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BIOVENTING TEST WORK PLAN FOR A-20 RADAR FACILITY (SITE SS-01) HURLBURT FIELD FIRE TRAINING AREA (SITE FT-39) EGLIN MAIN OLD FIRE TRAINING AREA (SITE FT-28)

Prepared For

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

Air Force Materiel Command
Eglin Air Force Base, Florida

Prepared By

ENGINEERING-SCIENCE
Atlanta, Georgia

December 1993

AQM01-03-0591

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BIOVENTING TEST WORK PLAN FOR A-20 RADAR FACILITY (SITE SS-01) HURLBURT FIELD FIRE TRAINING AREA (SITE FT-39) EGLIN MAIN OLD FIRE TRAINING AREA (SITE FT-28)

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

Air Force Materiel Command
Eglin Air Force Base, Florida

by

Engineering-Science, Inc.
57 Executive Park South, NE, Suite 500
Atlanta, Georgia

December 1993

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1.0 INTRODUCTION

This test work plan presents the scope of an *in situ* bioventing pilot test for treatment of fuel contaminated soils at the A-20 Radar Facility(Site SS-01), Hurlburt Fire training Area (Site FT-39) and Eglin Main Base Old Fire Training Area (Site FT-28) on Eglin Air Force Base (AFB), Florida. The pilot test has three primary objectives: 1) to assess the potential for supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms will degrade fuel when stimulated by oxygen rich soil gas, 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated below regulatory standards.

Pilot testing will consist of two phases, and initial air permeability and *in situ* respiration test which will take place in January 1993, and an extended one year pilot test which will be used to determine the potential for bioventing remediation using natural nutrient levels. The initial and extended pilot test will serve as treatability studies under the CERCLA feasibility study process. If bioventing proves to be feasible at these sites, pilot test data may be used to design a full scale remediation system and to estimate the time required for site cleanup.

The initial test will involve air injection at a vent well with a regenerative blower to produce a radius of influence of approximately 30 feet. *In situ* rates of fuel biodegradation and soil gas permeability will be determined during this short term test and a decision on how best to proceed with extended testing will be made with regulatory concurrence.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled *Test Plan and Technical Protocol For A Field Treatability Test For Bioventing* (Hinchee, et al. 1992). A copy of this protocol was submitted to Florida Department of Environmental Protection for work at Patrick AFB, Florida. The protocol document is a supplement to the site-specific work plan, and it will also serve as the primary reference for pilot test vent well designs and detailed test objectives and procedures. Unless otherwise noted, test procedures outlined in the protocol document will be used during the pilot tests at Eglin AFB.

2.0 SITE DESCRIPTION

2.1 Diesel/Solvent Contamination site, a-20 Radar Facility (SIte SS-01)

2.1.1 Site Location and History

The Diesel/Solvent Contamination Site (SS-01), was formerly known as IRP site A-20. This site is located at the A-20 Radar Facility in a remote area of Okaloosa County, Florida along the Santa Rosa/Okaloosa County line (**Figure 1**). To reach the site travel west on US 98 approximately 6.0 miles from the main gate at Hurlburt Field and turn right on Rosewood Drive. The site is approximately 0.8 miles from the intersection of US 98 and Rosewood Drive. The geographic coordinates are 30°25'16" N latitude and 86°47'54" W longitude.

2.1.2 Site Description

The area surrounding the site is generally undeveloped with the exception of a small residential community located approximately 0.4 miles south of the site. The total area of the facility is approximately 2 acres. The facility is positioned on relatively flat terrain which slopes gently toward a small swamp to the north. The facility boundary is rectangular in shape containing four buildings, an electric power switching station, a sewage treatment plant, an above-ground fuel storage area, and a groundwater recovery and treatment system (**Figure 2**). A chain-link fence surrounds the facility with three lockable gates to prevent unauthorized access to the site. A swamp area of less than twelve acres is located immediately north of the facility. The swamp is apparently bounded on three sides by higher ground and to the west by an unimproved road.

2.1.3 Operational History and Waste Characteristics

In the spring of 1984, Eglin personnel identified a diesel fuel spill, as indicated by fuel leaking into a sewage lift station located near the northwest corner of the radar building (**Figure 2**). The leak occurred during the storage and possibly handling of diesel fuel. The diesel fuel was stored in an above-ground storage tank located on the west side of the radar building and was used to operate a generator which supplied emergency power. Approximately 2,000 gallons of diesel fuel have leaked into the ground at the site. An additional source of subsurface contamination was also identified by early investigators as the sewage drain field. Apparently, the fuel which leaked into the sewage lift station through groundwater infiltration entered the sewage treatment plant via the sewage influent line, passed though the plant and discharged into the drain field.

The site is currently regulated under Florida Department of Environmental Protection (FDEP) Consent Order as ordered August 15, 1986. A groundwater recovery/treatment system and a free product recovery system were installed at the site in the fall of 1987, and began operating shortly thereafter. The system was designed to recover the free-floating fuel product and the dissolved constituent plume identified in the shallow groundwater beneath the site. The recovered groundwater was treated utilizing an on-site air stripping system which removed the volatile organic compounds

How much free product has been removed? Bioslurper? Off gas treatment?

Figure 1

SITE LOCATION MAP
A-20 RADAR FACILITY
DIESEL/SOLVENT CONTAMINATION SITE - (SITE SS-01)
EGLIN AFB, FLORIDA

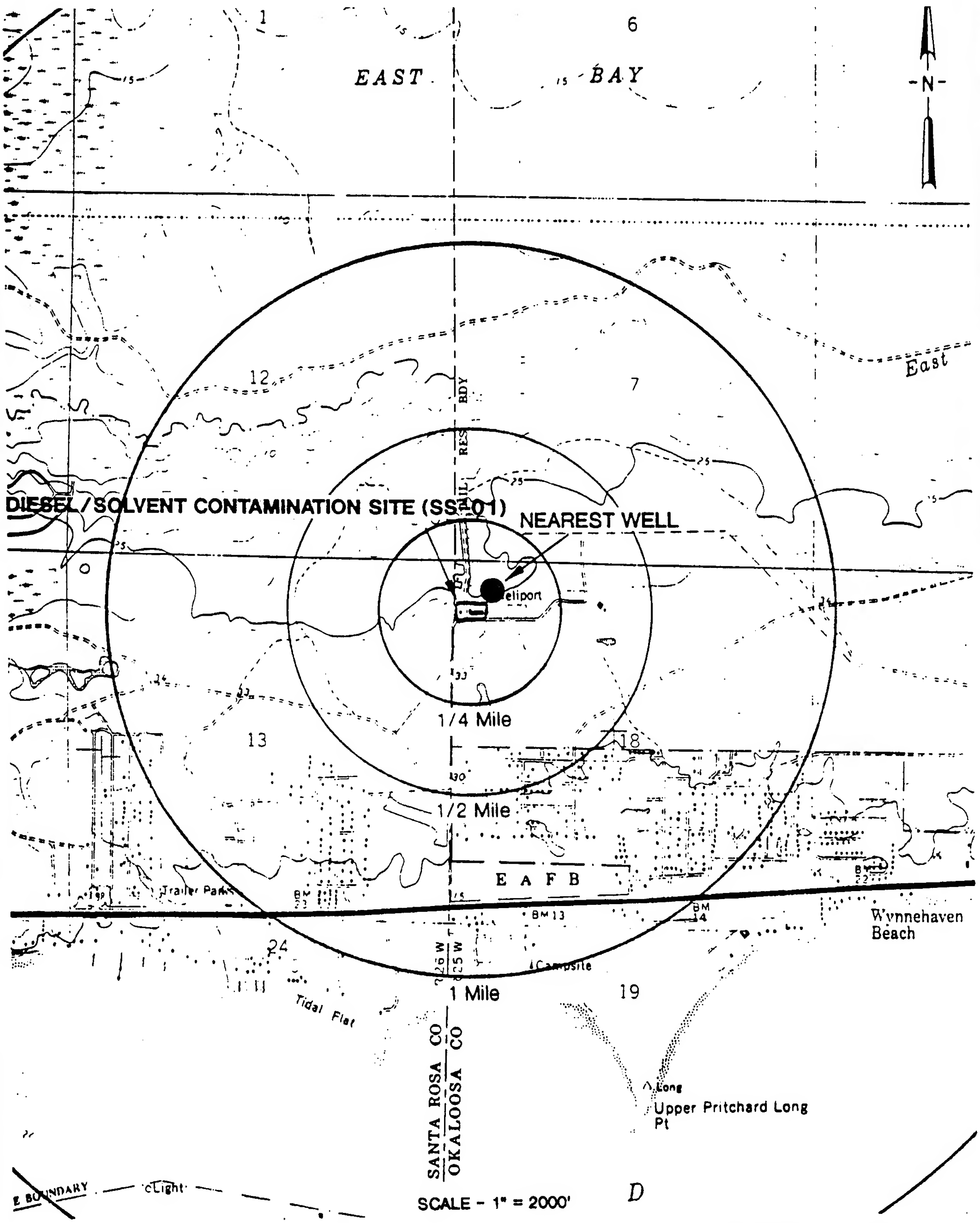

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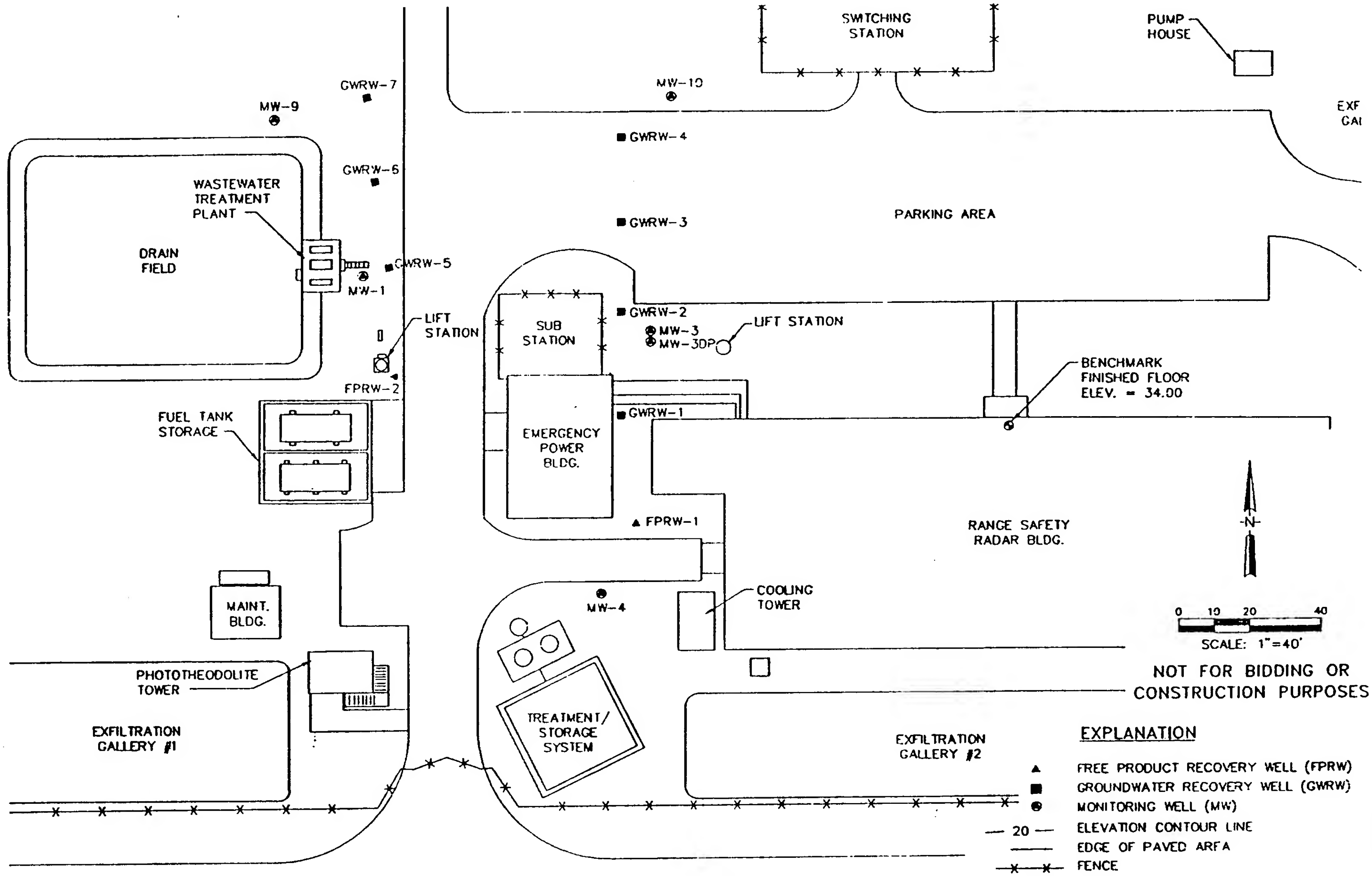
Figure 2

SITE LAYOUT MAP
A-20 RADAR SITE
DIESEL/SOLVENT CONTAMINATION SITE (SITE SS-01)
EGLIN AFB, FLORIDA



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from the recovered groundwater. The stripped effluent was subsequently discharged into the system's exfiltration galleries. (**Figure 2**). The groundwater recovery/treatment system remained operational until December of 1987 at which point, the system was shut down for technical evaluation and modification. In January of 1992, system modifications and repairs were made and the recovery/treatment system resumed operation. Historically, the diesel spill extended over the road west of the radar building and covered only a limited amount of soil area.

2.1.4 Site Geologic and Hydrogeologic Characteristics

2.1.4.1 Groundwater

Three predominant geologic features underlie Site SS-01: the sand-and-gravel aquifer, the Pensacola clay formation, and the limestones comprising the Floridan aquifer system. The surficial sands and gravels extend to an approximate depth of 390 feet below land surface (bls). The underlying Pensacola Clay is approximately 280 feet thick in the area and extends to a depth of approximately 670 feet bls (ES, 1992). A series of limestone and dolomite lithologies, the Tampa and Chickasawhay Formations underlie the Pensacola Clay. The Tampa and Chickasawhay Formations are characterized as vesicular limestone and dolomite. The Bucatunna Clay, a massive calcareous, fossiliferous clay of low permeability, in turn underlies these two carbonate formations in this area of the base. The Ocala Group, a permeable fossiliferous limestone, resides below the Bucatunna Clay. The Ocala Group , in turn, is underlain by the Claiborne Group, a series of limestones and shales of low permeability.

Groundwater occurs in two primary aquifer systems at the A-20 Radar Facility; the surficial sand-and-gravel aquifer and the deep Floridan aquifer system (ES, 1992). The sand-and-gravel aquifer is utilized primarily for irrigation purposes while the Floridan aquifer system serves as the primary source of drinking water for Eglin AFB and the surrounding municipalities.

The sand-and-gravel aquifer occurs under unconfined or water table conditions at the site. Groundwater occurs in the surficial sand-and-gravel aquifer between four and six feet below land surface (bls). The generalized groundwater flow direction in the surficial aquifer is towards the north-northeast as indicated by past groundwater levels in the site monitoring wells. Water levels in the deep monitoring well, MW3 (screened 45-50 feet bls), indicate a downward vertical component of groundwater flow in the shallow sand-and-gravel aquifer. Results from a pumping test conducted during the recovery system installation indicate that the estimated transmissivity of the uppermost portion of the sand-and-gravel aquifer is approximately 3,400 gallons per day per foot.

The lower boundary of the sand-and-gravel aquifer is formed by the Pensacola Clay, a low permeability unit that serves as a nearly impervious layer and effectively isolates the sand-and-gravel aquifer from the Floridan aquifer system.

The depth to the top of the Floridan aquifer system is approximately 670 feet bls. The transmissivity of the aquifer ranges from 250 to 50,000 feet squared per day (ES, 1992). The Floridan Aquifer system in the area has minor karst features.

2.1.4.2 Soil Contamination

Why?

No soil samples have been analyzed at this site for TPH. However, diesel contamination has been detected visually during drilling operations. Site SS-01 is covered by asphalt, concrete, grass and crushed oyster shells. No signs of vegetative stress were observed at the facility during site reconnaissance.

2.2 Hurlburt Field Fire Training AREA (SITE FT-39)

2.2.1 Site Description, Operational History, and Waste Characteristics

2.2.1.1 Site Location

The Hurlburt Fire Training Area (FTA of Site FT-39) is located approximately one mile west of Mary Esther, Florida (**Figure 3**). To reach the FTA, exit Eglin Main Base via the west access gate onto State Route #85. Proceed 3.4 miles and take State Route #20 west near Ocean City. Follow this road, also known as Racetrack Road, for 3 miles into the City of Wright. Enter Hurlburt Field on Heritage Road. This road will intersect Golf Course Road within 2.3 miles of the base boundary. Go south at the intersection and take two quick right turns. The FTA is on the left near the Golf Course Maintenance Facility (building #91310) (**Figure 3**). The geographic coordinates are 30°25'58" N latitude and 86°41'02" W longitude.

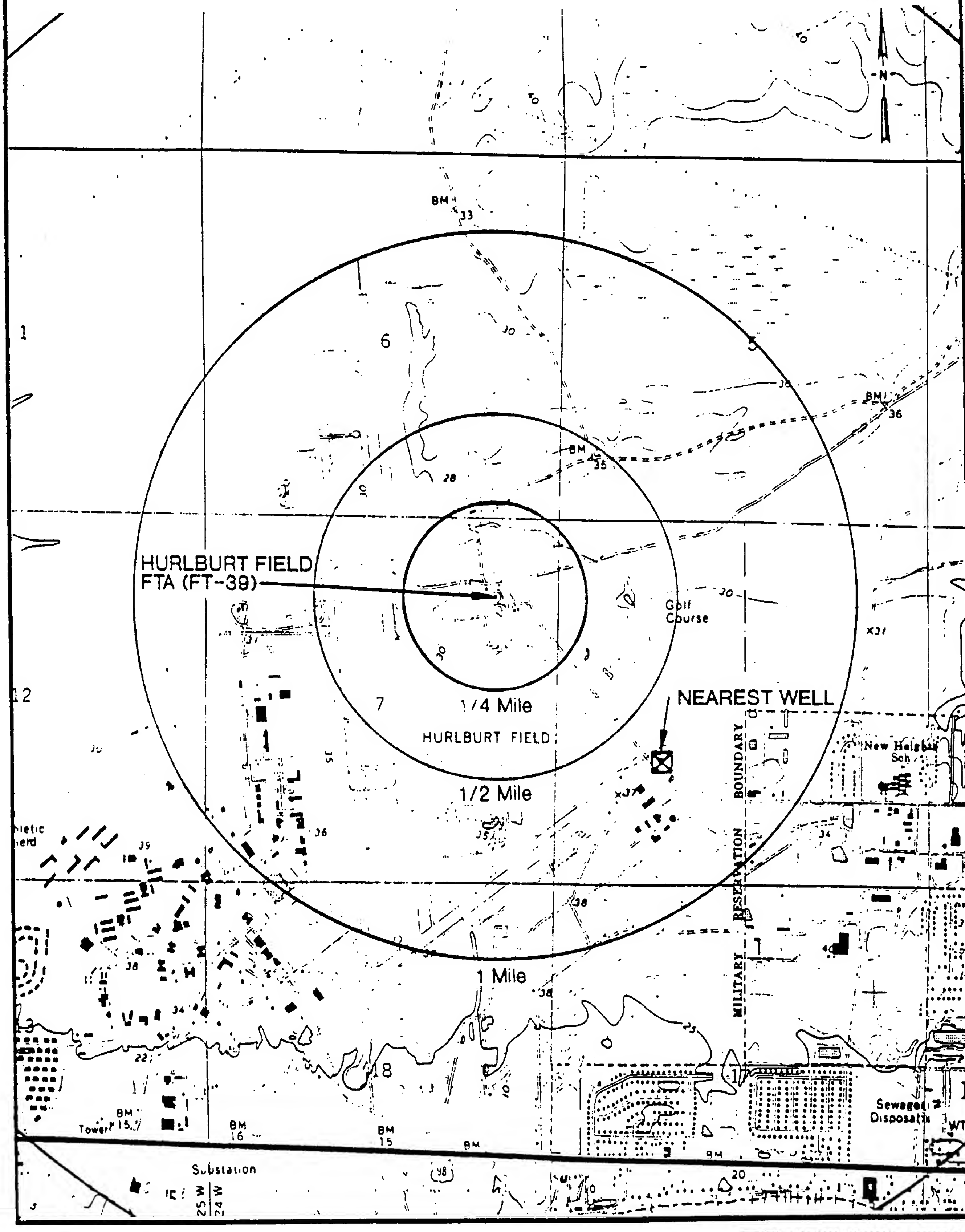
2.2.1.2 Site Description

The Hurlburt FTA is defined by a large, cleared circular area surrounded by earthen berms nearly six feet in height (**Figure 4**). This abandoned burn area was nearly 50 feet in diameter with a six-inch concrete berm along the periphery for fuel containment. An asphalt apron for fire fighting vehicles was also provided. Recent site visits revealed that the burn pad has been paved. A concrete liner has been constructed under the FTA. Residual fuels, water, and AFFF (an extinguishing agent) flow to an oil/water separator near the southern edge of the site and are removed. The effluent was then discharged to a drainage ditch leading to the swamp.

The site is in an isolated area on the eastern side of Hurlburt Field N-S runway. Base activities in the immediate vicinity of the FTA are limited. The majority of the operations associated with Hurlburt Field are centralized on the west side of the airfield. The field's eastern portion is primarily comprised of inundated swampland, a golf course, and a golf course maintenance shop (building #91310). No base personnel regularly work directly on the FTA site. However, a small staff (less than 20 persons) conducts operations and maintenance functions for the Hurlburt golf course within 200 feet of the site. The site is accessible to anyone with base clearance.

Figure 3

SITE LOCATION MAP
HURLBURT FIELD FTA - (SITE FT-39)
EGLIN AFB, FLORIDA



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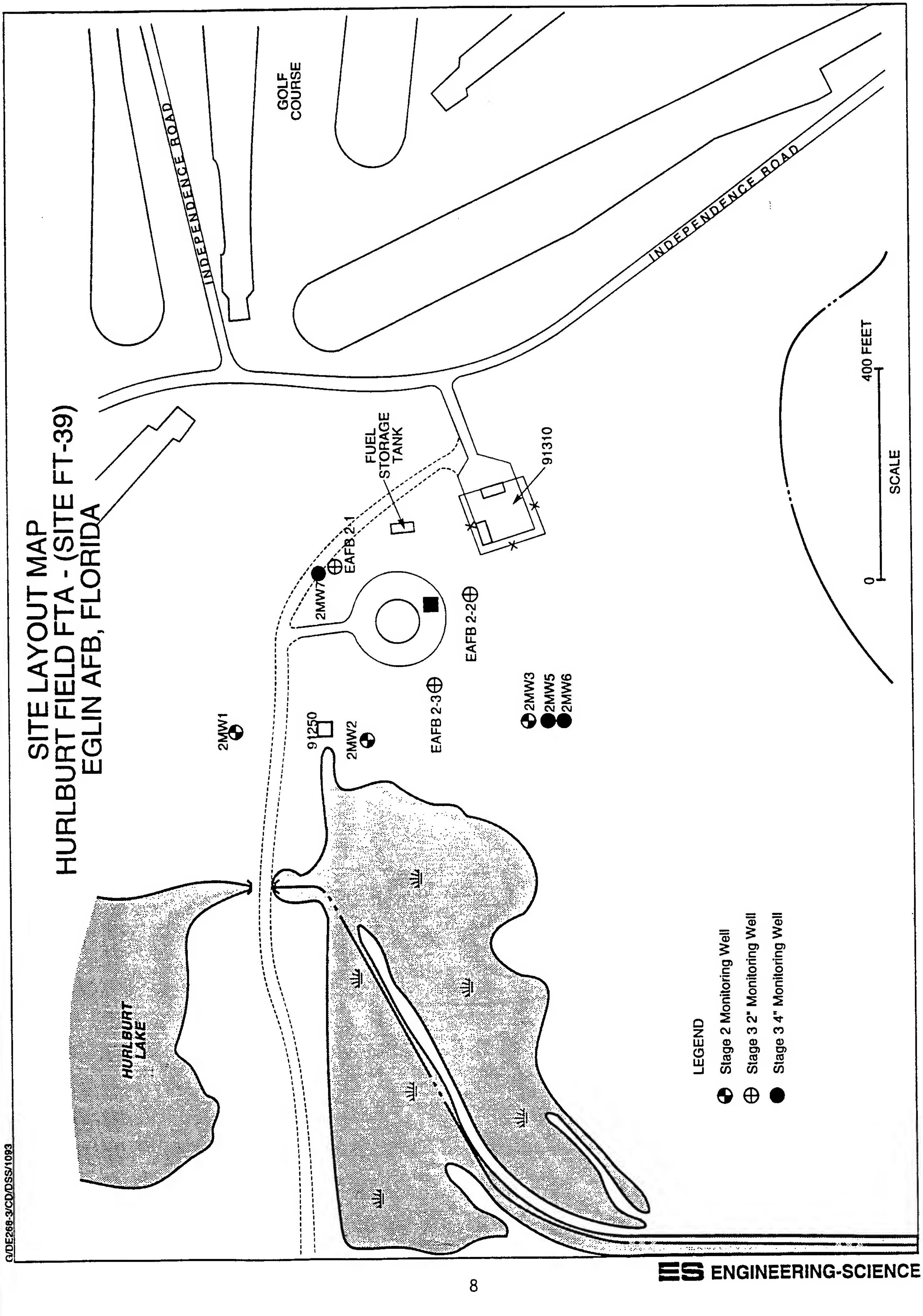

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The updated Preliminary Assessment site reconnaissance was conducted on September 18, 1991. The FTA is surrounded by a large earthen berm and completely covered by an asphalt cap. The central burn area was not distinguishable as described during previous site visits. The base guide who accompanied the field team explained that fire training activities had not been held onsite for over two years. An old helicopter and other vehicles at the FTA are now used for welding practice. No visual evidence of past burning activities were observed. Inspection of an old above ground fuel tank did not reveal any stained soils or fuel odors. The surface water runoff path was not well defined as a result of apparent site rework since the Stage 3 investigation. Vegetation along the southern edge, outside the berm, appeared to exhibit signs of stressedconditions. Within the enclosed area the grasses were discontinuous, but this may be the result of recent activities.

2.2.1.3 Operational History and Waste Characteristics

The Hurlburt FTA site was used for the training of personnel in the Fire Protection Division Department and at the same time for the disposal of waste fuels, oils, solvents, and contaminated fuels. The site has been active from the late 1950s to 1989, however, the frequency of use in recent years was greatly reduced from the typical two to three fires per week prior to the mid 1960s. Furthermore, pollution concerns caused a reduction in the quantities of fuels used and limited the extinguishing agent to primarily water.

The common practice used during training exercises involved spraying fuel onto representative mock buildings, planes, and cars. Since the burn pad was originally equipped with a concrete berm, much of the fuel remained confined and was easily ignited. After a specified time, chemicals (AFFF and water) were applied to extinguish the fire. Ideally, any unburned fuel was then diverted to a nearby oil/water separator. Discharge from the separator then flows southwest to a drainage ditch leading to Hurlburt Lake.

The Installation Restoration Program IRP Phase I investigation of the Hurlburt FTA did not indicate a high priority for further evaluation (ES, 1981). However, at the request of the Air Force Systems Command the site was included in the IRP Phase II, Stage 2 investigation (ES, 1988). Three monitoring wells were installed, with respect to inferred groundwater flow, around the periphery of the FTA. Each of the wells was less than 20 feet deep and installed in the surficial aquifer. Static groundwater level measurements confirmed the surficial groundwater flow direction was generally northwest toward Hurlburt Lake.

Soil samples were collected prior to well construction and three additional boring locations were selected along the edge of the asphalt apron. Five of the six boring samples displayed either stained soil and/or exhibited strong fuel odors at depths less than 15 feet bls. Chemical analyses was not performed on soil samples during this field effort.

Why?

The IRP Phase II, Stage 3 field effort began in April 1988 and was designed to obtain additional data to further characterize the site. A soil gas survey was conducted to aid in soil boring and well sitings. This information was used to advance five soil borings to the soil-water interface and install six monitoring wells. In addition, all three of the in-place wells were resampled.

The soil gas survey identified the presence of benzene, toluene, and TCE. The results of toluene concentration are presented in **Figure 5**. The highest detections were under the asphalt apron and extended to the south near the oil/water separator. The results of the soil boring samples revealed total petroleum hydrocarbons as high as 1900 mg/kg in the soils collected from the western edge of the site. The four other soil borings were free of detectable petroleum hydrocarbon contamination.

The remedial action recommended consisted of capping the site to avoid further contaminant migration via infiltration and ceasing fire training activities. Natural degradation/dilution for groundwater contamination was selected since no receptors were identified and groundwater discharges into the swamp. In addition, no wells exist between the site and the swamp. The implementation of a bioventing pilot test and a long term monitoring plan was selected as the remedial alternative for the site.

2.3 Eglin Main Base Old Fire Training Area (Site FT-28)

2.3.1 Site Description, Operational History and Waste Characteristics

2.3.1.1 Site Location

The Eglin Main Base Old Fire Training Area (FTA) is located west of the north-south runway and north of Taxiway Number 6 on the main base of Eglin Air Force Base, in southeastern Okaloosa County, Florida. The geographic coordinates for the site are 30° 28 ' 47 " N Latitude and 86° 31 ' 09 " W Longitude. A site location map of the Eglin Main Base Old FTA has been included as **Figure 6**.

2.3.1.2 Site Description

The Eglin Main Base Old FTA consists of an area of flat, sparsely vegetated terrain containing a shallow burn pit approximately seventy five feet in diameter. The burn pit is surrounded by a crumbling earthen berm and contains a partially burned, mock aircraft. Abandoned storage tanks, automobile parts, and a fuel truck were noted during recent site reconnaissance for the Preliminary Assessment of this site. A site layout map of the Eglin Main Base Old FTA has been included as **Figure 7**.

The immediate vicinity of the site includes the north-south runway at Eglin Main Base, a taxiway, and associated base buildings. The FTA is currently used as an initial training facility; fire-training exercises involving the use of flammable liquids are no longer conducted at the site.

Figure 5

ISONCONCENTRATIONS OF TOLUENE IN SOIL GAS HURLBURT FIELD FTA - (SITE FT-39) EGLIN AFB, FLORIDA

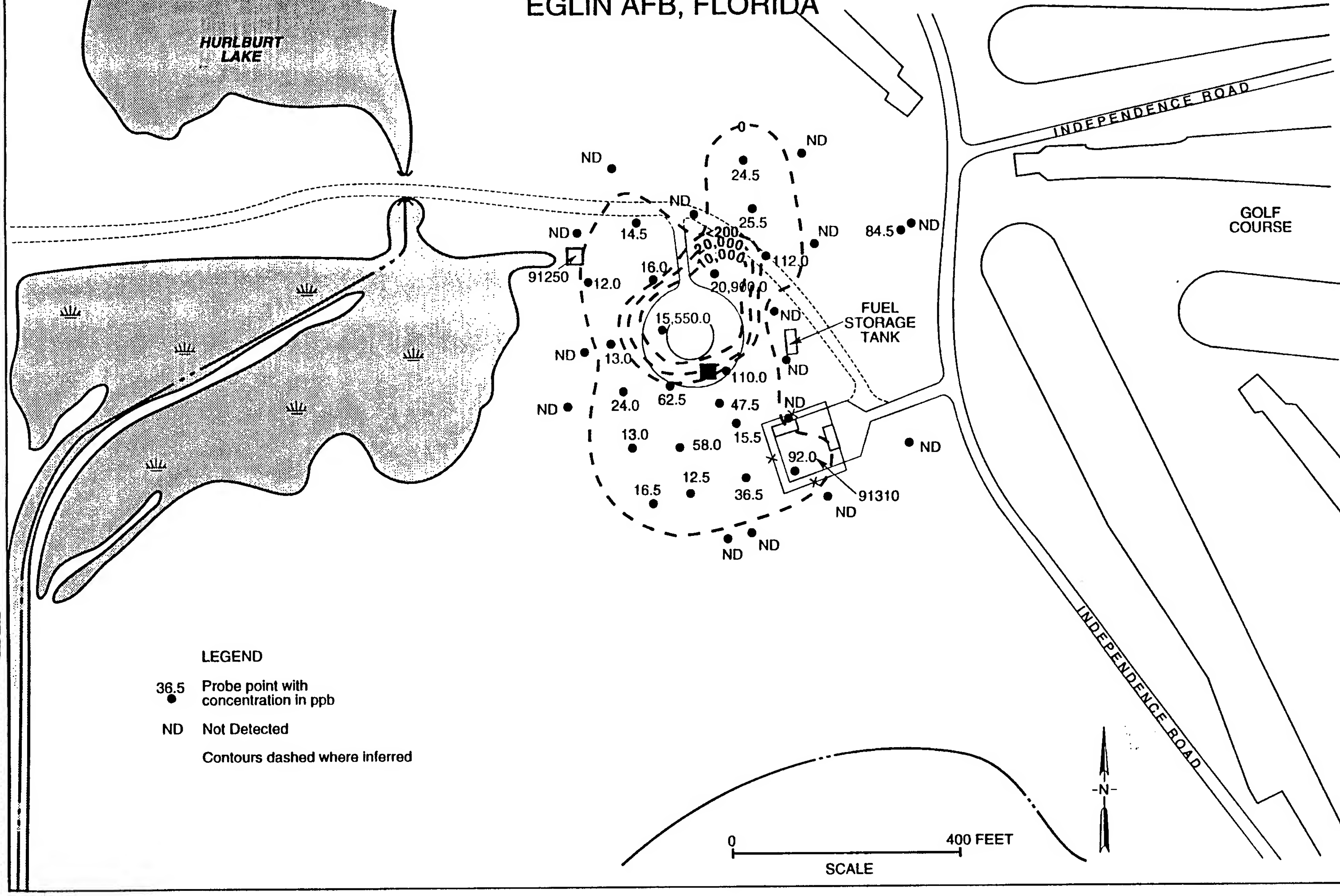

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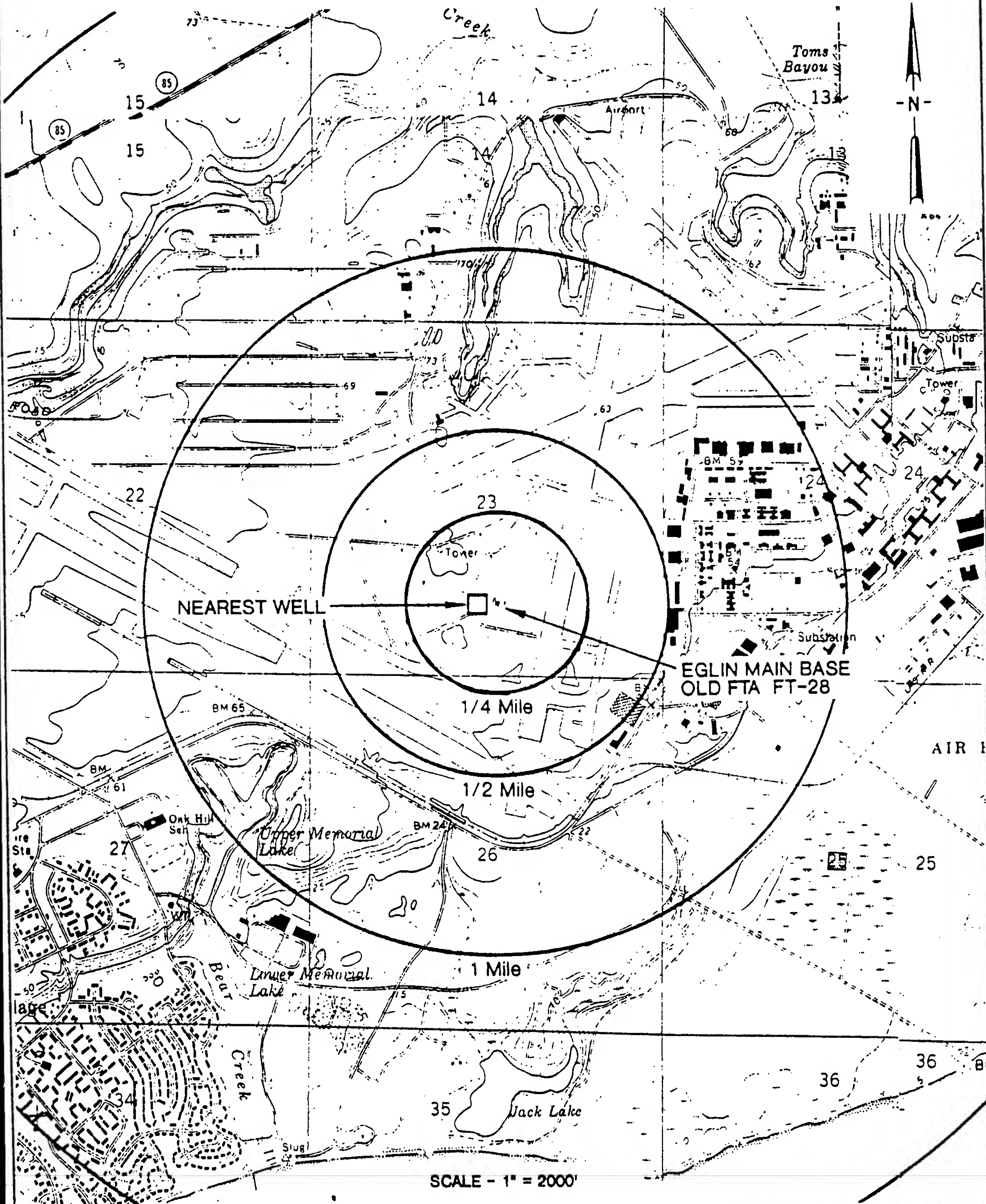
Figure 6

SITE LOCATION MAP
EGLIN MAIN BASE OLD FTA - (FT-28)
EGLIN AFB, FLORIDA



SCALE - 1" = 2000'

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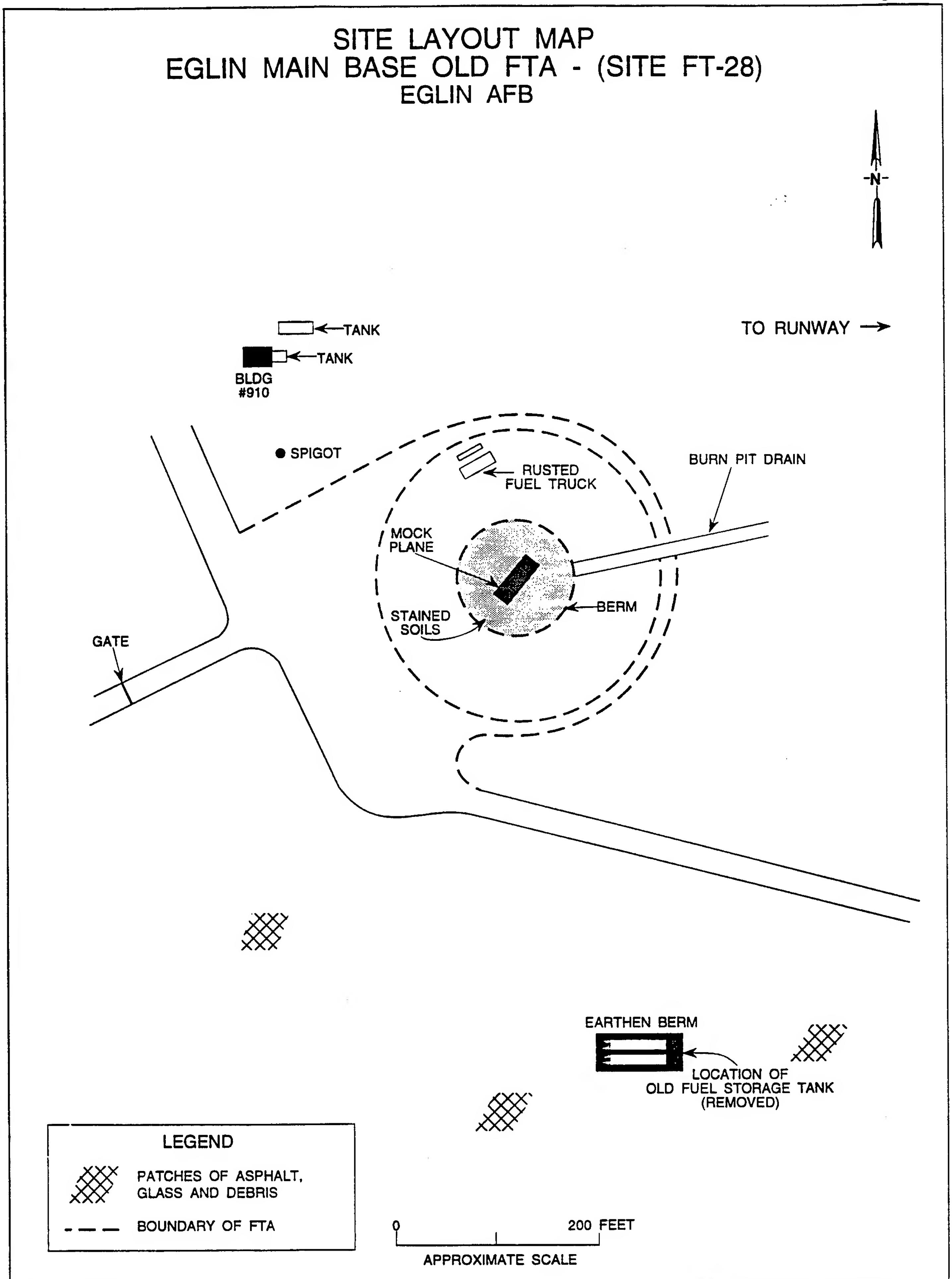
Figure 7



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2.3.1.3 Waste Characteristics and Operational History

During its operation as an active fire training area, the Eglin Main Base Old FTA was used to conduct training exercises intended to simulated the fires associated with aircraft accidents (ES, 1992). Flammable liquids were transferred to the burn pit from a tanker truck or by a buried pipe from a tank adjacent to the burn pit area. After ignition, the fires were rapidly extinguished with water or with a diluted solution of aqueous film forming foam (AFFF). After the exercise, residual fuels, AFFF and water remained in the burn pit.

During the 1950s and 1960s, flammable materials such as waste fuel, oil, and water-contaminated fuels and solvents were used. The frequency of fire training exercises was sharply reduced during the 1970s due to environmental concerns. Following the reduction in exercises and the increase in environmental concern, the flammable liquids used were limited to JP-4 and JP-4 contaminated with water (ES, 1992).

At the request of the Systems Command, this site was included in the Installation Restoration Program Phase II, Stage 2 investigation. Based on the results of this investigation and a preliminary soil gas survey, which detected benzene, chlorobenzene, toluene, xylene and trichloroethylene in the subsurface soils, the FTA was included in the IRP Phase II, Stage 3 Remedial Investigation/Feasibility Study (ES, 1992). The objective of this study was to confirm the concentration and extent of contamination in soil and groundwater at the site, and to estimate the rate of contaminant migration.

During the Stage 3 investigation, samples were collected from ten soil borings, and six groundwater wells that were installed at the site at depths ranging from 50 to 100 feet bls. Soil samples were analyzed for volatile organics, petroleum hydrocarbons, lead, and physical characteristics including soil moisture and organic carbon content.

2.3.1.4 Soil Contamination

Soil samples were collected at the site from near the surface to the groundwater interface. Analyses of these samples detected petroleum hydrocarbons at concentrations ranging from 110 to 11,000 mg/kg. The highest TPH concentrations (500 to 11,000 mg/kg) occurred in soils within 10 feet below ground surface. However, TPH was also detected in soils at a depth of about 40 feet. Purgeable aromatics were also detected. Xylenes, the most predominant of the aromatics, were present at concentrations ranging from 9.8 mg/kg to 41,000 mg/kg. Benzene was detected at concentrations ranging from 0.10 mg/kg to 160 mg/kg. Ethylbenzene and toluene were present in lower concentrations. Soil samples also contained chlorobenzene 1,1,2,2-tetrachloroethane, and methylisobutyl ketone. The concentrations of these compounds were all below 10 mg/kg. No semi-volatile organic compounds were detected in any of the soil samples collected.

Soil samples were also analyzed for lead to determine the impact of leaded fuels used in fire training activities. Lead was reported in several samples at concentrations ranging from 2 to 51 mg/kg. Concentrations were greater in near-surface soils. The

highest concentration was detected in a surface soil sample collected from the burn pit. Results of a soil gas survey depicting benzene concentration is presented in **Figure 8**.

3.0 PILOT TEST ACTIVITIES

3.1 Introduction

The purpose of this section is to describe the work that will be performed by Engineering-Science, Inc. (ES) at Site SS-01, Site FT-28 and Site FT-39 at Eglin AFB. Activities performed at each site will include siting and construction of a central vent well (VW) and three vapor monitoring points (VMPs); an *in situ* respiration test; an air permeability test; and the installation of an extended bioventing pilot test system. Soil and soil gas sampling procedures and blower configuration that will be used to inject air (oxygen) into contaminated soils are also discussed in this section. In an effort to be as cost effective as possible, a single VW will be completed to the depth of lowest seasonal groundwater at each site. Pilot test activities will be confined to unsaturated soils remediation. Existing monitoring wells will not be used as primary air injection or extraction wells. However, monitoring wells which have a portion of their screened interval above the water table may be used as VMPs or to measure the composition of background soil gas. Existing monitoring wells at each site may also be monitored during air permeability testing.

3.2 Well Siting and Construction

3.2.1 A-20 Radar Facility

A general description of criteria for siting a single central VW and associated VMPs at each site are included in the attached protocol document. **Figure 9** illustrates the proposed location of the central VW and VMPs at Site SS-01. The final location of the VW may vary slightly from the proposed location if significant fuel contamination is not observed in the boring for the central VW. Based on previous site investigation data, the VW will be located by the Fuel Tank Storage. The area is expected to have a high TPH concentration. Soils in this area are expected to be oxygen depleted (<2%) and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during full-scale operations.

Due to the relatively shallow depth of contamination at this site and the potential for moderate permeability soils, the radius of venting influence around the central air injection well in the pit is expected to expected to be approximately 30-40 feet. Three VMPs will be located within a 40-foot radius of the central VW. Background monitoring for this test will be conducted at either an existing background monitoring point or at a background vapor monitoring point located approximately 100 feet southeast of the leak area. Well MW-4 is a potential candidate for the background well. The location of this well is shown on **Figure 9**. If a background vapor monitoring well has to be installed, it will be constructed in the vicinity of well MW-4 during the initial field work. The background well would be used to measure background levels of oxygen and carbon

Figure 8

ISOCONCENTRATIONS OF BENZENE IN SOIL GAS
EGLIN MAIN BASE OLD FTA (FT-28)
EGLIN AFB, FLORIDA

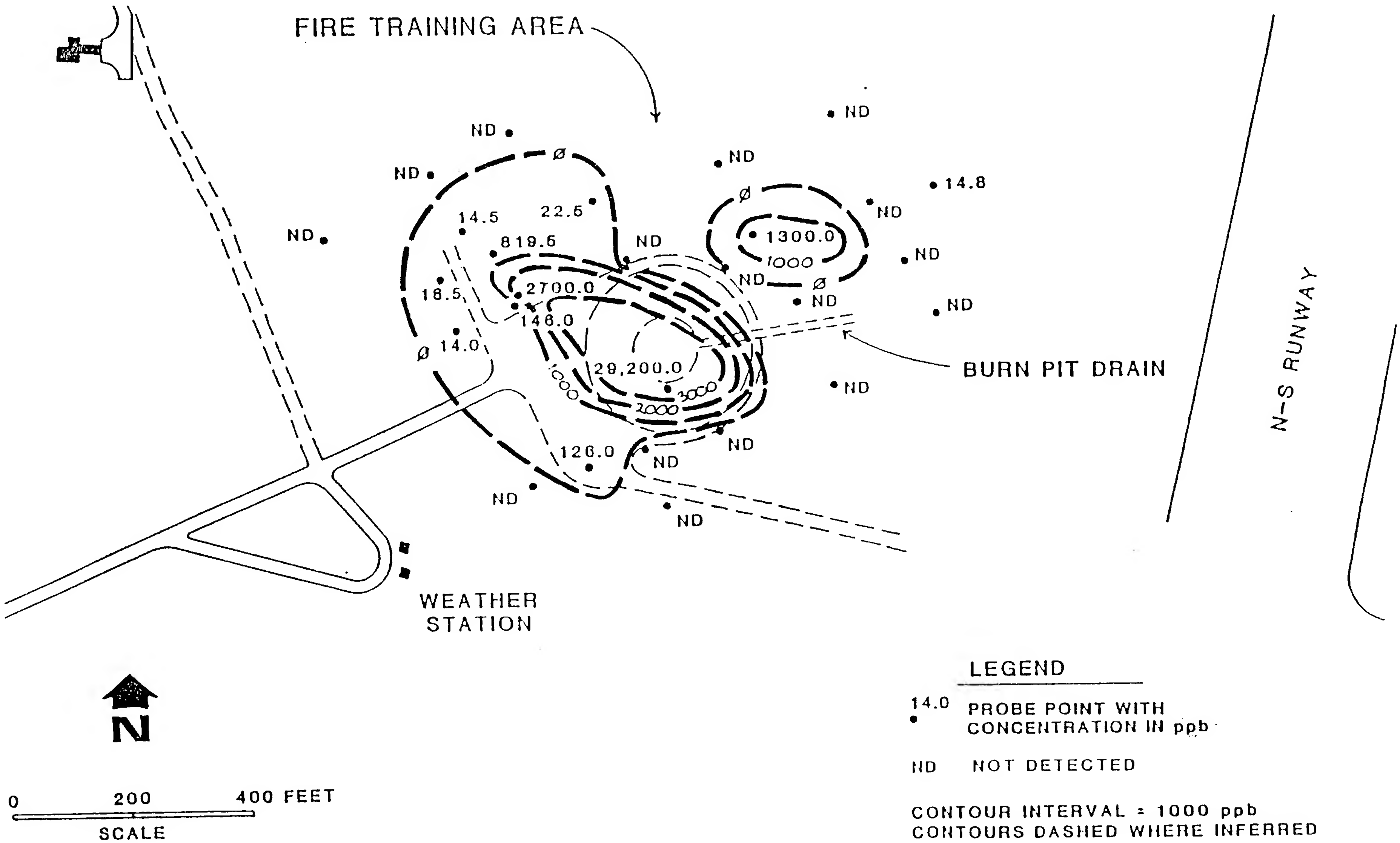

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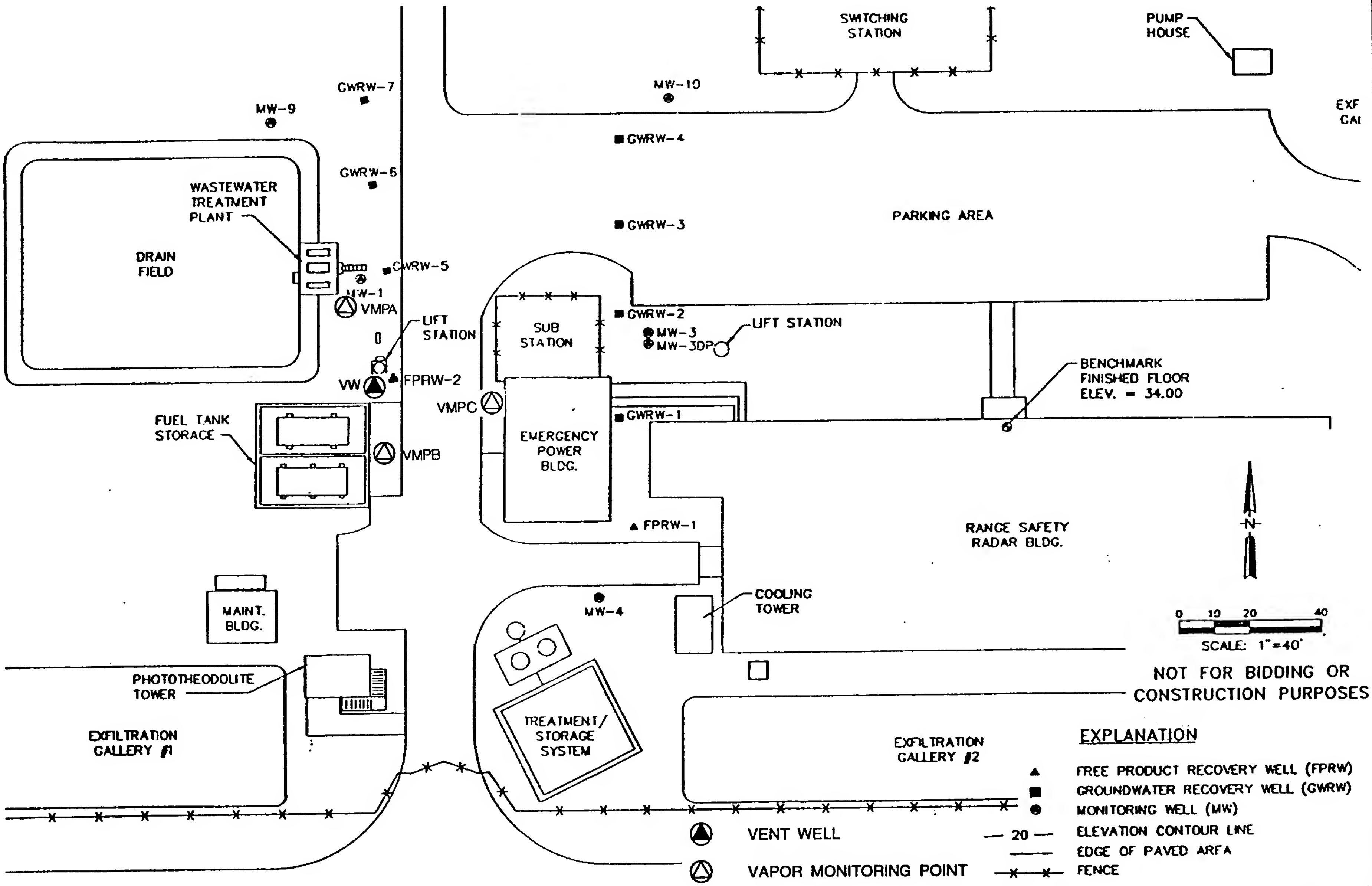
Figure 9

PROPOSED VENT WELL AND VAPOR MONITORING POINTS
A-20 RADAR SITE
DIESEL/SOLVENT CONTAMINATION SITE (SITE SS-01)
EGLIN AFB, FLORIDA



6-9 silica sand ? see Fig 10. ?

dioxide and to determine if natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test.

7.5

The VW will be constructed of 4-inch ID Schedule 40 PVC, with a 20-foot interval of 0.04 slotted screen set between 3 and 8 feet BGS (groundwater occurs at depths between 5 and 7 feet below ground surface). Flush-threaded PVC casing and screen will be used with no organic solvents or glues. The filter pack will be clean, well-rounded silica sand with a 8-12 grain size and will be placed in the annular space of the screened interval. A 1-foot layer of bentonite will be placed directly over the filter pack. The bentonite will consist of granular bentonite and/or pellets hydrated in place with potable water to produce an air tight seal above the screened interval. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. Silica sand and cement grout will placed over the slurry and extend to the ground surface. **Figure 10** illustrates the proposed central VW construction details for this site.

A typical multi-depth VMP installation for this site is shown in **Figure 11**. Soil gas oxygen and carbon dioxide concentrations will be monitored at depth intervals of approximately 2 to 3 feet, and 5 to 6 feet at each location (the deepest monitoring point will be set at approximately 1 foot above the deepest seasonal groundwater elevation). Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen and be used to measure fuel biodegradation rates at all depths. The annular space between these three monitoring points will be sealed with bentonite to isolate the monitoring intervals. As with the central vent well, granular bentonite or pellets will be used to create the air tight seal between discreet depth monitoring points. Additional details on VW and monitoring point construction are found in Section 4 of the protocol document and the addendum provided in Appendix D.

2 or 3 monitoring points?

3.2.2 Hurlburt Field Fire Training Area (FT-39)

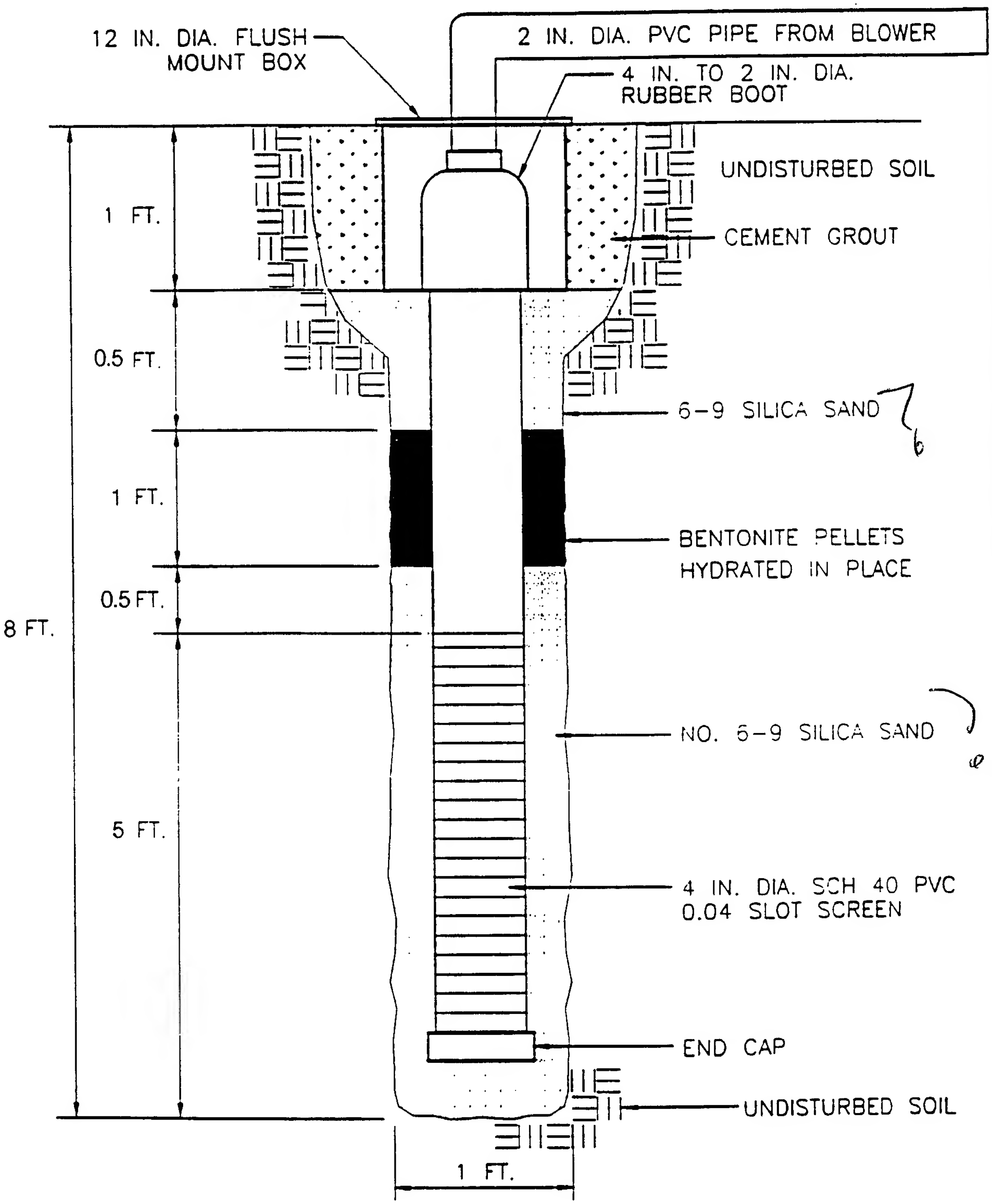
The method used for well siting and construction for the A-20 Radar Facility will be identical to those used for the Hurlburt Fire Training Area. The vent well will be screened from 3 to 8 below ground surface (bgs), and the monitoring depth interval will be approximately 3 to 4 feet, and 5 to 6 feet. **Figure 12** illustrates the proposed location of the central VW and VMPs at Site FT-39. **Figure 13** illustrates the proposed central VW construction details for this site.

Reverse the wording.

3.2.3 Eglin Main Old Fire Training Area (FT-28)

The method used for well siting and construction for the A-20 Radar Facility will be identical to those used for the Eglin Main Old Fire Training Area except that a deeper vent well and vapor monitoring wells will be required.. The vent well will be screened from 6 to 41 below ground surface (bgs), and the monitoring depth interval will be approximately 5 to 6 feet, 25 to 26 feet, and 40 to 41 feet. **Figure 14** illustrates the proposed location of the central VW and VMPs at Site FT-28. **Figure 15** illustrates the proposed central VW construction details for this site.

INJECTION VENTING WELL CONSTRUCTION DETAIL
A-20 RADAR FACILITY
DIESEL/SOLVENT CONTAMINATION SITE (SITE SS-01)
EGLIN AFB, FLORIDA



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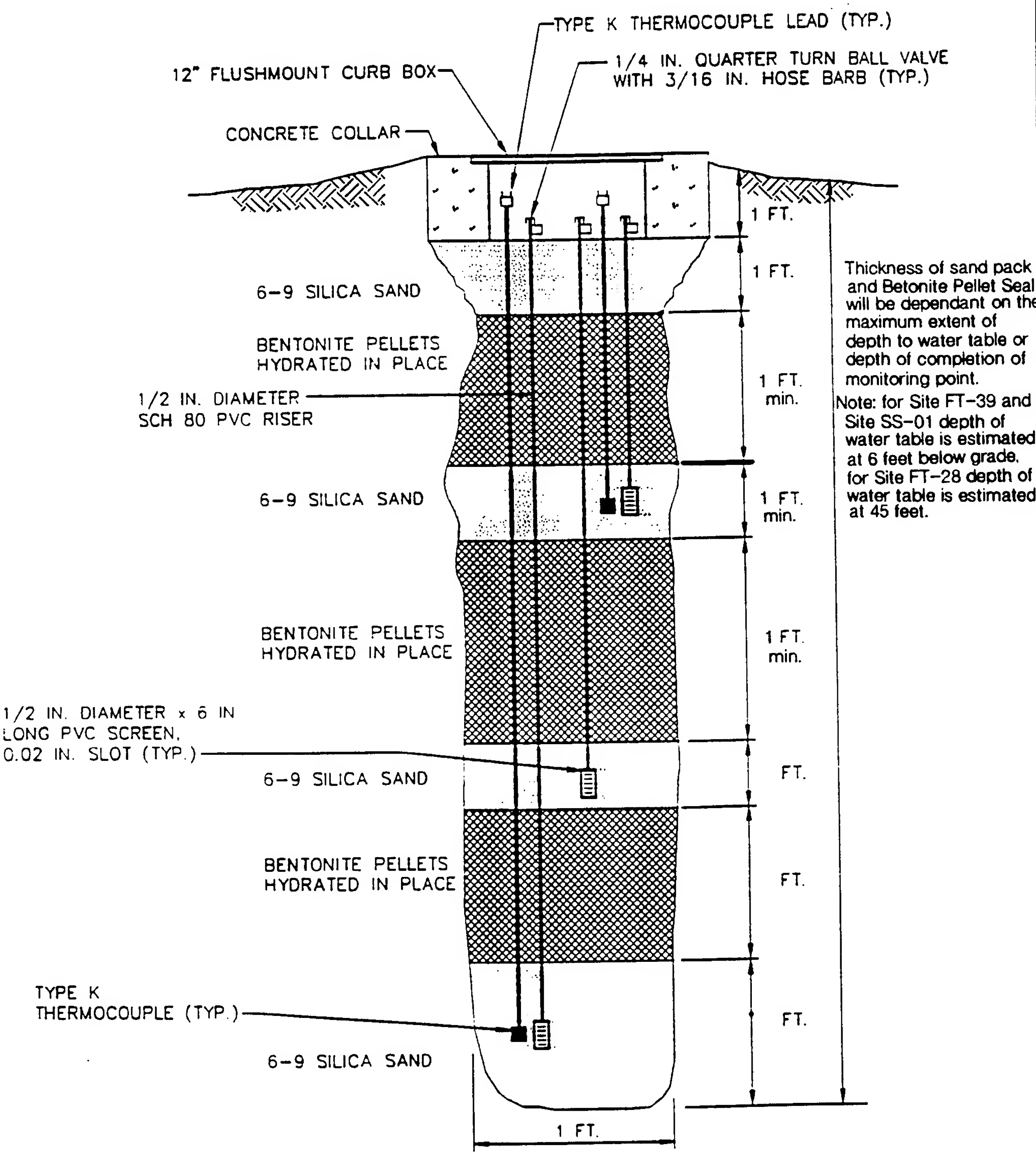
ES ENGINEERING-SCIENCE

Figure 11

TYPICAL VAPOR MONITORING POINT



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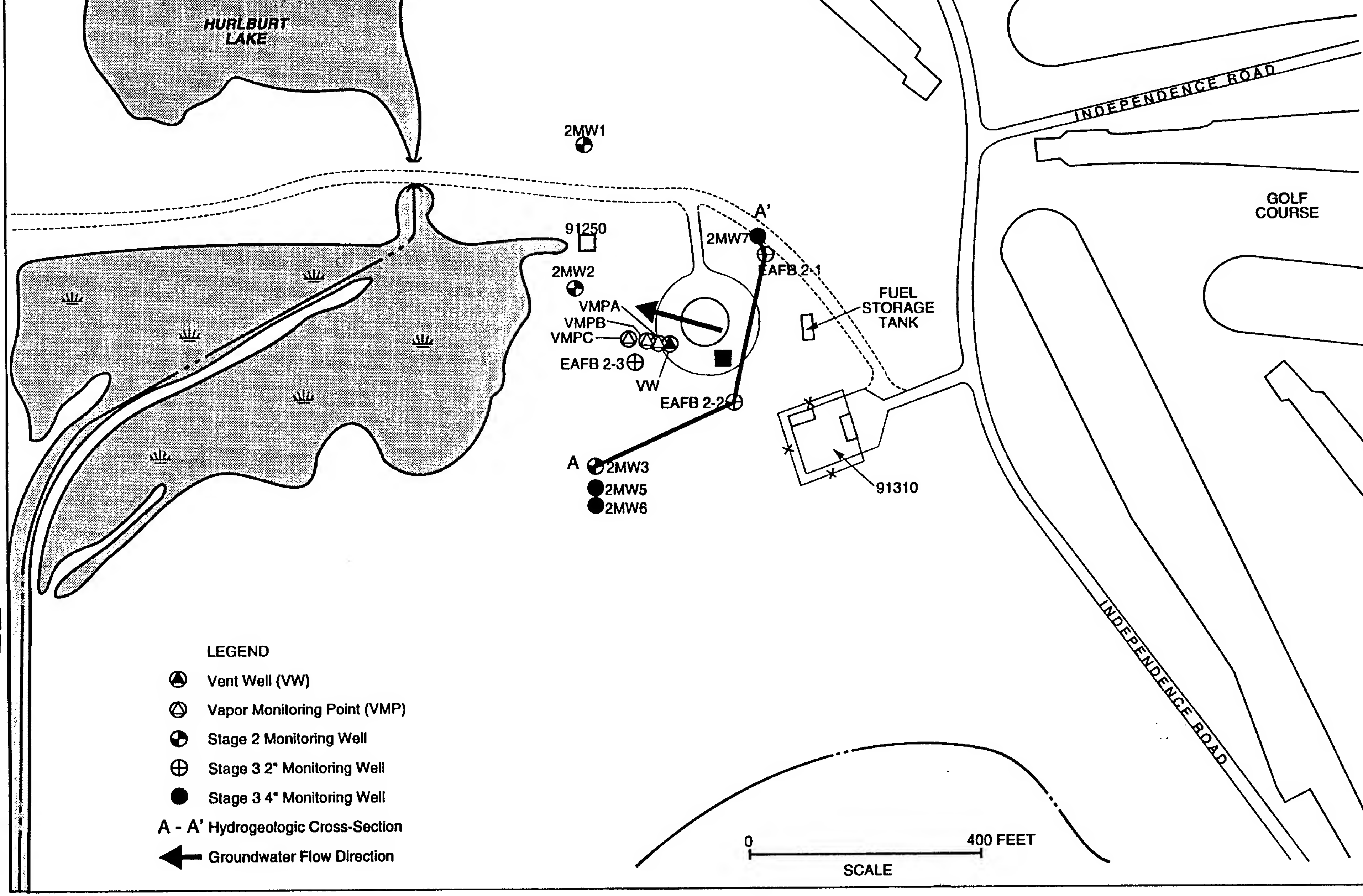
ES ENGINEERING-SCIENCE

Figure 12

PROPOSED VENT WELL AND VAPOR MONITORING POINTS
HURLBURT FIELD FTA - (SITE FT-39)
EGLIN AFB, FLORIDA



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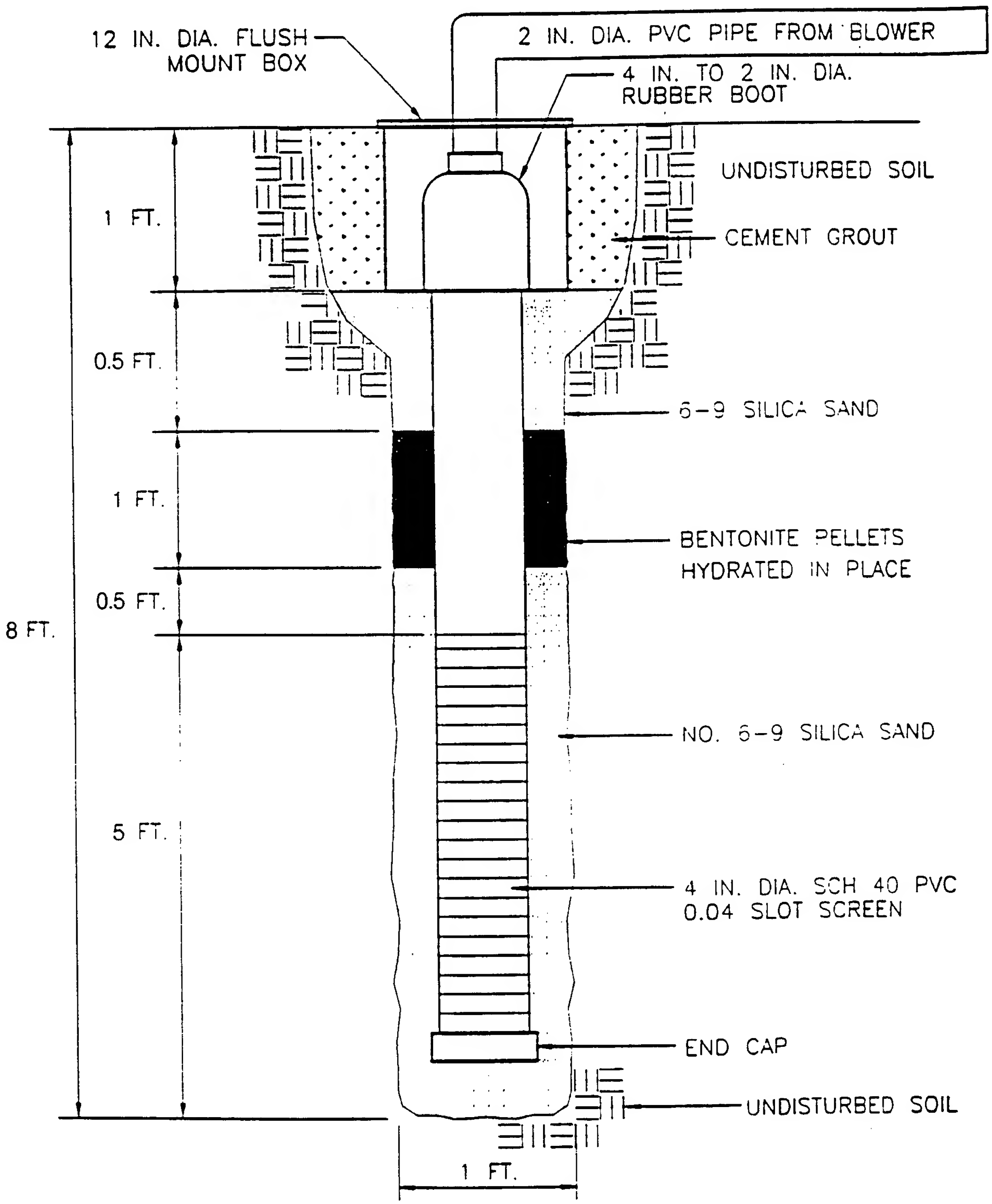
INJECTION VENTING WELL CONSTRUCTION DETAIL
HURLBURT FIELD FTA - (SITE FT-39)
EGLIN AFB, FLORIDA



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PROPOSED VENT WELL AND VAPOR MONITORING POINTS EGLIN MAIN BASE OLD FTA - (SITE FT-28) EGLIN AFB

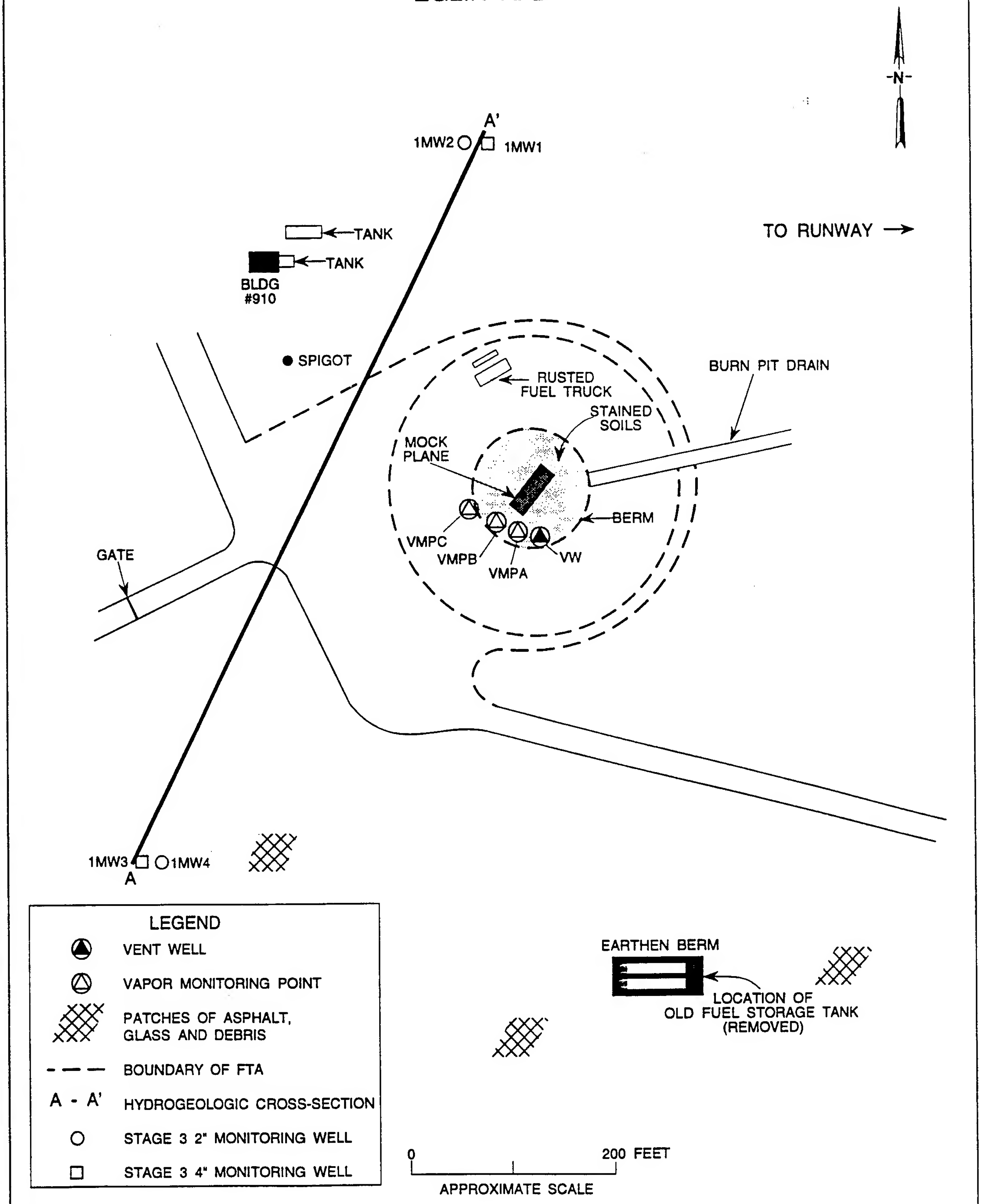

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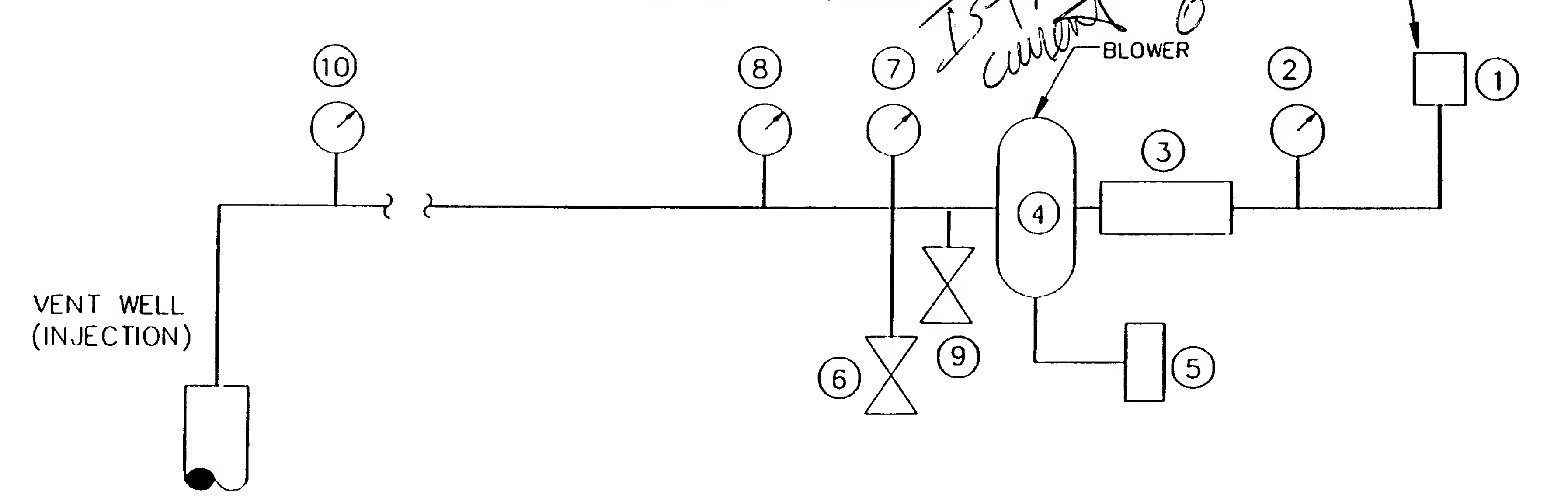
Figure 15

SCHEMATIC OF BLOWER SYSTEM FOR AIR INJECTION
JP-5 LEAK AREA
AIR FORCE PLANT 6, GEORGIA



1. INLET FILTER
2. VACUUM GUAGE (INCHES OF H O)
3. DRIVE MOTOR
   1 HP / 3450 RPM @ 60 Hz / 230v / SINGLE PHASE / 15 A
4. BLOWER - GAST R4110-2 / REGENERATIVE
   70 SCFM @ 20 INCHES H O
5. POWER SWITCH
6. AUTOMATIC PRESSURE RELIEF VALVE - SET @ 42 INCHES H O
7. PRESSURE GUAGE (INCHES OF H O)
8. THERMOMETER (FAHRENHEIT)
9. MANUAL PRESURE RELIEF (BLEED) VALVE - 1 1/2" BALL
10. AIR VELOCITY MEASUREMENT PORT

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3.3 Handling of Drill Cuttings

Soil cuttings obtained during monitoring point and vent well construction will be drummed, labeled, and stored onsite pending evaluation of final disposal option by the Eglin AFB point of contact. Does this mean the base takes responsibility for the cuttings?

3.4 Soil and Soil Gas Sampling

3.4.1 Soil Sampling

Three soil samples will be collected during the pilot test at the time of VW and VMP installation. One sample will be collected from the most contaminated interval of the central VW boring and one sample will be collected from the interval of highest apparent contamination in two of the borings drilled for VMP installations. Soil samples will be analyzed for TPH, BTEX, soil moisture, pH, particle sizing, alkalinity, total iron and nutrients.

Samples will be collected using a split-spoon sampler containing brass tube liners. A photoionization detector or total hydrocarbon vapor analyzer (see protocol Section 4.5.2) will be used to insure that breathing zone levels of volatiles do not exceed 1 ppm during drilling and to screen split spoon samples for intervals of high fuel contamination. Soil samples collected in the brass tubes will be immediately trimmed and aluminum foil and a plastic cap placed over the ends. Soil samples will be labeled following the nomenclature specified in the protocol document (Section 5.5), wrapped in plastic, and placed in an ice chest for shipment. A chain of custody form will be filled out and the ice chest shipped to the Pace Laboratory in Huntington Beach, California, for analysis. This laboratory has been audited by the U.S. Air Force and meets all quality assurance/quality control and certification requirements for the State of California.

Is this current?

3.4.2 Soil Gas Sampling

A total of three soil gas samples will be collected in SUMMA™ canisters in accordance with the *Bioventing Field Sampling Plan* (ES, 1992) (Appendix C). The samples will be collected from the VW, and from the VMPs closest to and furthest from the VW at the site. These soil gas samples will be used to predict potential air emissions, to determine the reduction in BTEX and total volatile hydrocarbons (TVH) during the 1-year test, and to detect any migration of these vapors from the source area.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the Air Toxics laboratory in Folsom, California for analysis. The procedure for collecting these samples are presented in the Field Sampling Plan (FSP) (Appendix C, Section C.2). Sample analysis, type, number, container, and preservatives are also presented in Table C.1 in the FSP.

3.5 Blower System

A 1.0-HP blower capable of injecting 30 - 40 scfm will be used to conduct the initial air permeability test. This blower provides a wide range of flow rates and should develop sufficient pressure to move air through moderate permeability soils. Air injection will be used to provide oxygen to soil bacteria and to minimize emissions of volatiles to the atmosphere. If initial testing at the site indicates that less pressure is required to supply oxygen, a smaller blower will be installed for extended testing (1 year pilot test)..

An extended pilot test will be performed if results of initial pilot testing indicate oxygen utilization rates that confirm presence of biological activity is positive. The extended bioventing test will be initiated following a review of initial test data. **Figure 16** is a schematic of a typical air injection system that will be used for pilot testing at these sites. A conceptual cross section design for the bioventing system at each site is presented on **Figures 17, 18, and 19**.

The maximum power requirement anticipated for this pilot test is a 230-volt, single-phase, 30-amp service. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

3.6 Air Monitoring

The bioventing technique will minimize total emissions of more volatile hydrocarbons to the atmosphere. This is accomplished by reducing air injection rates to supply only the minimum required oxygen to sustain the indigenous microorganisms. By supplying only the required oxygen for biodegradation, volatilizations effects caused by excess air injection is minimized.

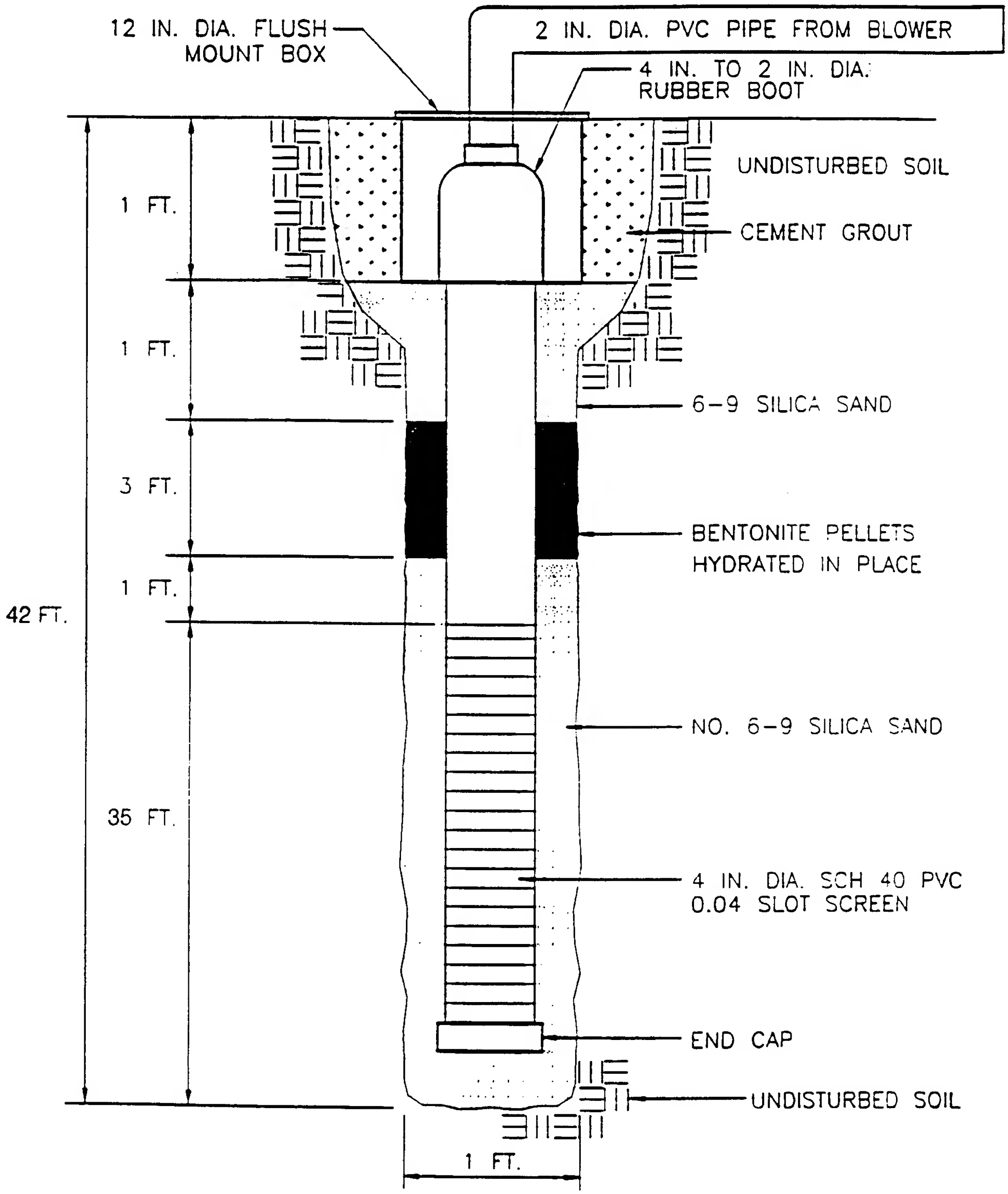
During all activities involving air injection, the air at the ground surface and at the breathing zone within a 20 foot radius of the injection well will be monitored for volatile hydrocarbons by use of a photoionization detector. Air monitoring will be done to ensure safe working conditions and to provide a rough estimate of volatilization loses, if they occur. More intense air monitoring is required during the first eight hours of the air permeability test because the potential for emissions of the more volatile hydrocarbons is greatest at that time.

The potential for emissions at these sites is low because of the age of the fuel residuals and asphalt cover at two of the sites. The depth of air injection at one of the sites (site FT-28) without asphalt cover would also minimize potential for air emission. Flux emissions measured at a similar site at another Air Force base with similar aged contaminants and soil type showed less than 5 grams of fuel hydrocarbons emitted to the atmosphere per hour of operation, or less than 0.26 pounds per day.

3.7 In Situ Respiration Test

The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons in the presence of oxygen. Respiration tests

INJECTION VENTING WELL CONSTRUCTION DETAIL
EGLIN MAIN BASE OLD FTA (SITE FT-28)
EGLIN AFB, FLORIDA



Not To Scale

Figure 17

CONCEPTUAL CROSS-SECTION DESIGN FOR BIOVENTING PILOT TEST AT A-20 RADAR FACILITY DIESEL/SOLVENT CONTAMINATION SITE (SITE SS-01) EGLIN AFB, FLORIDA

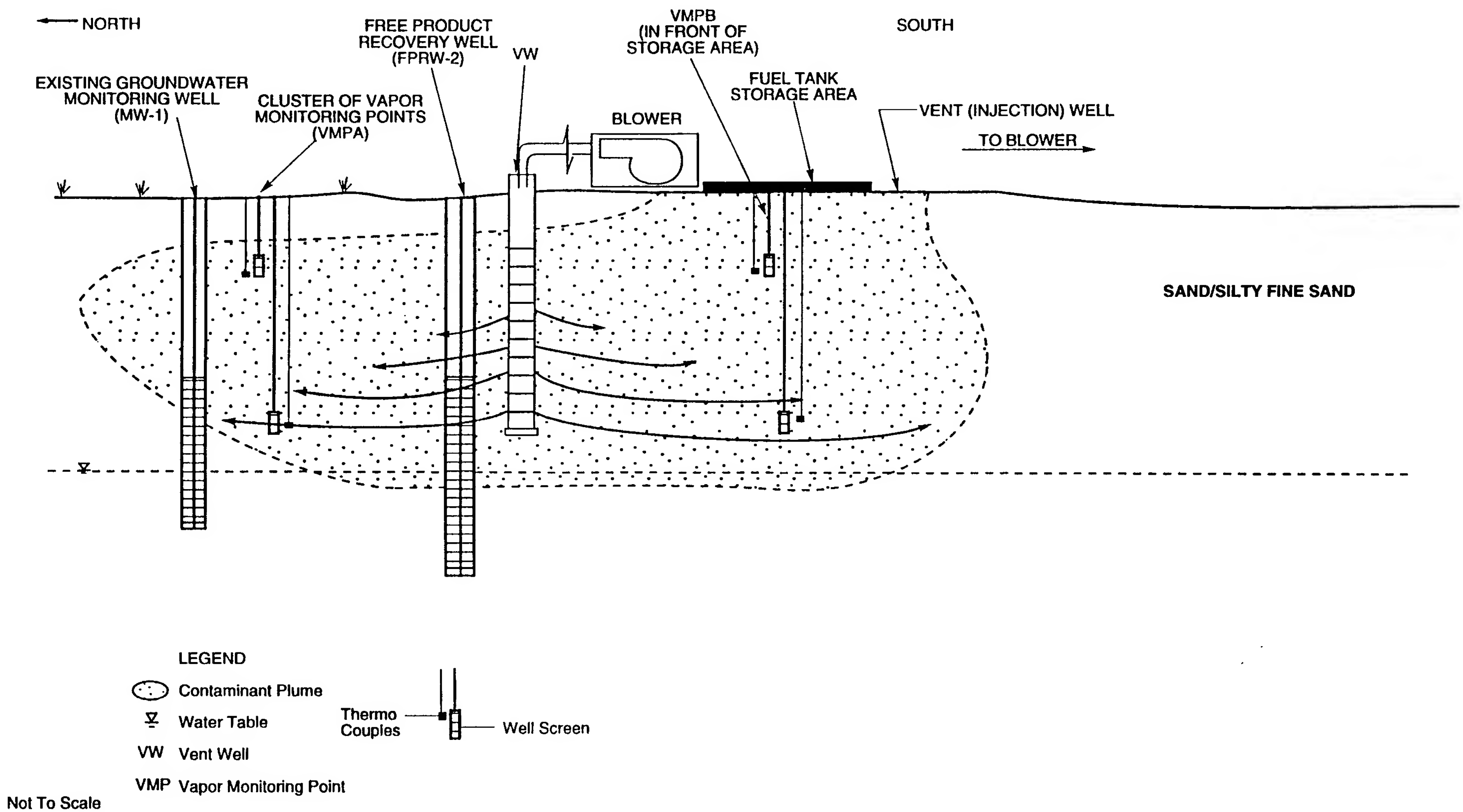
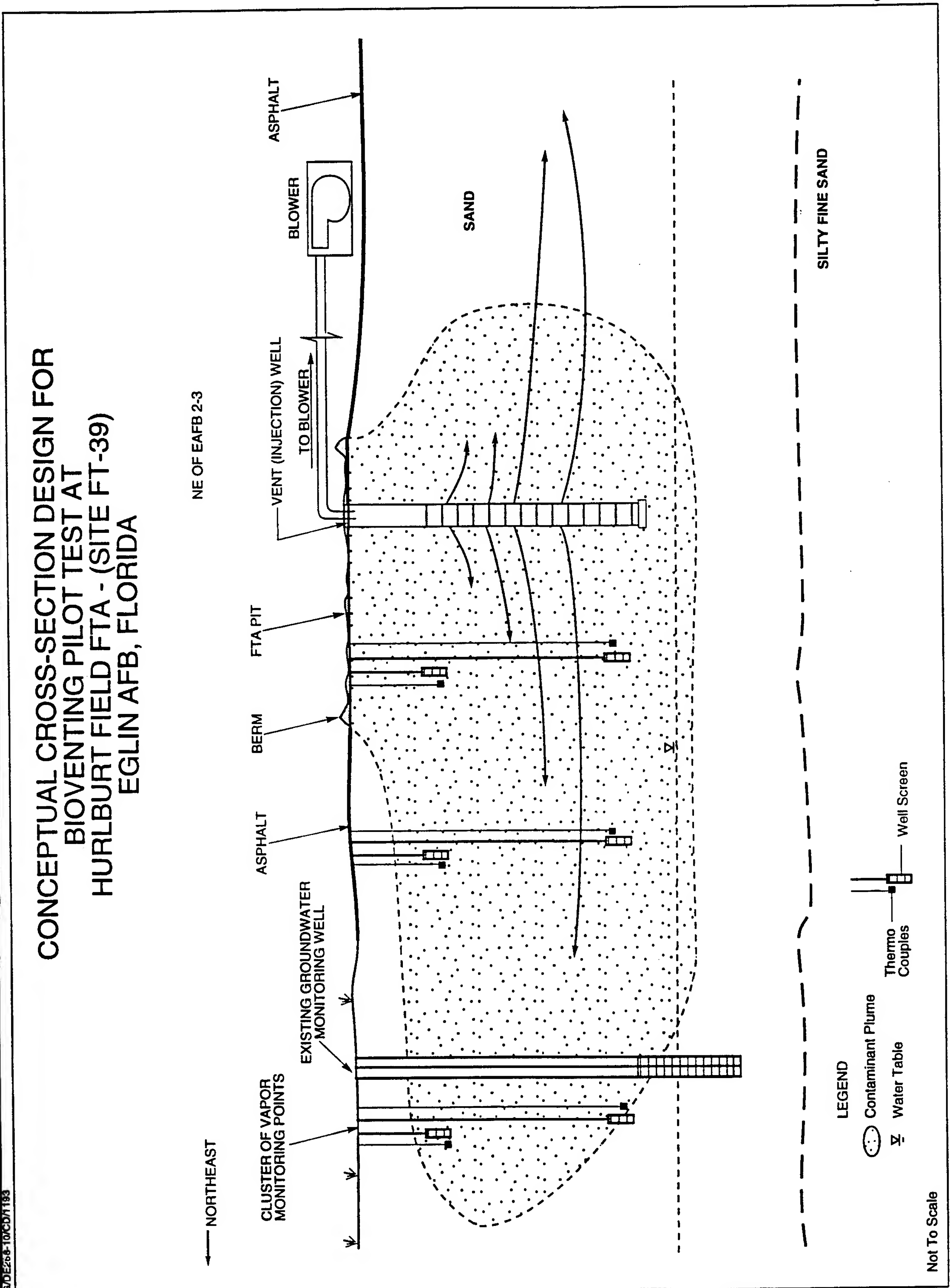


Figure 18

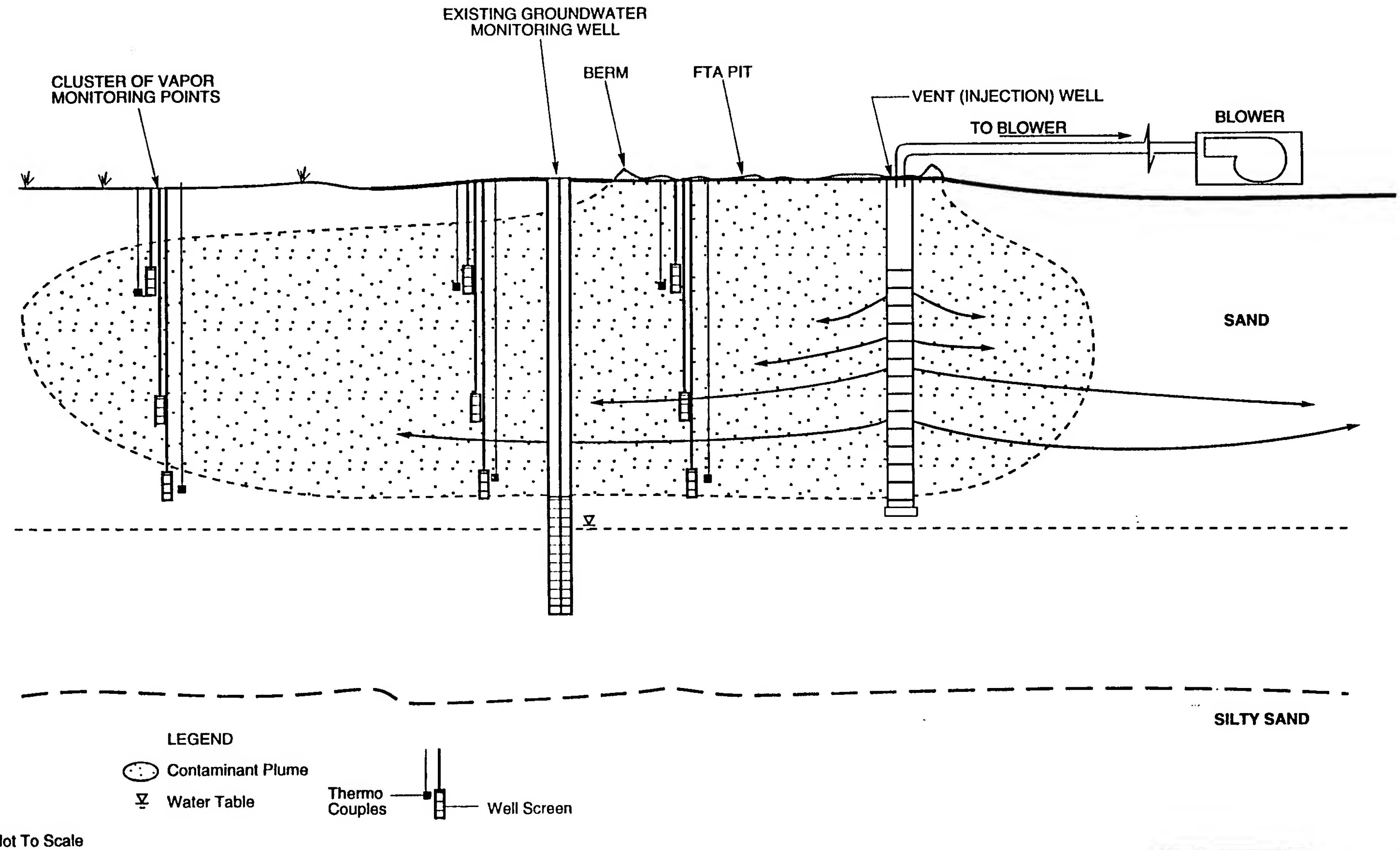


CONCEPTUAL CROSS-SECTION DESIGN FOR BIOVENTING PILOT TEST AT HURLBURT FIELD FTA - (SITE FT-39) EGLIN AFB, FLORIDA

ES ENGINEERING-SCIENCE

Figure 19

CONCEPTUAL CROSS-SECTION DESIGN FOR BIOVENTING PILOT TEST AT EGLIN MAIN BASE OLD FTA - (SITE FT-28) EGLIN AFB, FLORIDA



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will be performed at the three VMP points with the highest apparent fuel contamination at each site. Air will be injected into each VMP depth interval containing low levels (< 2%) of oxygen. A 20 to 24-hour air injection period will be used to oxygenate local contaminated soil. At the end of the air injection period, the air supply will be cut off, and oxygen and carbon dioxide levels will be monitored for five days or until the oxygen level falls below 5%, whichever is earlier. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals.

Concurrent to the air injection period, a helium tracer will also be injected at the VMPs at a concentration of two to five percent. Helium levels will be monitored along with the oxygen and carbon dioxide levels to ensure that the VMPs do not leak. Additional details on the *in situ* respiration test are found in Section 5.7 of the protocol document.

3.8 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using one air injection VW. Air will be injected into the 4-inch-diameter VW using the blower unit, and pressure response will be measured at each VMP with differential pressure gauges to determine the region influenced by the unit. Oxygen will also be monitored in the VMPs to verify that oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 4 to 8 hours will be performed.

3.9 Installation of Extended Pilot Test Bioventing System

An extended, 1-year bioventing pilot system will be installed at each site. The decision to proceed with the bioventing pilot system for a year will be based on the results of the degradation rate calculations. From previous studies, the oxygen utilization rates that can be expected from sites contaminated with jet fuel are between 0.05 to 1.0% O_2/hour. If rates within this range are obtained and are significantly greater than background, there is sufficient evidence to assume that some microbial activity is occurring and that the addition of O_2 in these contaminated areas will enhance biodegradation. If soil gas O_2 levels are above 2 to 5% prior to any air injection, or if oxygen utilization rates are not greater than background, venting will most probably not stimulate biodegradation and consideration will be given to terminate the bioventing effort.

The base will be requested to provide a power pole with a 230-volt, single-phase, 30-amp breaker box. Two 115-volt receptacles will also be required. Depending on the availability of a base electrician, a base electrician or a licensed electrician subcontracted to ES will assist in wiring the blowers to line power. The blower will be housed in a small, prefabricated shed to provide protection from the weather.

The system will be in operation for 24-hours per day for 1 year. Air injection rates of less than 30 SCFM are anticipated at each site. After six months and 12 months of

operation, ES personnel will conduct follow-up *in situ* respiration tests to monitor the long-term performance of this bioventing system. Weekly system checks will be performed by Eglin AFB personnel. If required, major maintenance of the blower unit may be performed by ES personnel. Detailed blower system information and a maintenance schedule will be included in the operation and maintenance (O&M) manual provided to the base. More detailed information regarding the test procedures can be found in the protocol document.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used to measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document. No exceptions to this protocol are anticipated.

5.0 BASE SUPPORT REQUIREMENTS

The following base support is needed prior to the arrival of a driller and the ES test team:

- Confirmation of regulatory approval for the pilot test.
- Assistance in obtaining a digging permit at the site.
- A breaker box within 100 feet of the proposed VW which can supply 230-volt, single-phase, 30-amp service for the initial and extended pilot test.
- Provision of any paperwork required to obtain gate passes and security badges for approximately four ES employees and two drillers. Vehicle passes will be needed for two trucks and a drill rig.

During the initial three week pilot test the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as near to the site as practical.
- The use of a fax machine for transmitting 15 to 20 pages of test results.

During the one year extended pilot test the following base support is needed:

- Check the blower system at each site at least once a week to ensure that it is operating and to record the air injection pressure. Engineering-Science will provide a brief training session on this procedure.
- Notify Mr. Ola Awosika (404) 235-2371, ES-Atlanta, or Mr. David Brown, ES-Syracuse, (315) 451-9560; or Mr. Marty Faile of the AFCEE, (210) 536-4342, if the blower or motor stop working.
- Arrange site access for an ES technician to conduct *in situ* respiration tests approximately six months and one year after the initial pilot test.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan.

Event	Date
Draft Work Plan to AFCEE & Eglin AFB	December 1993
Regulatory Approval	January 1994
Begin Pilot Test	February 1994
Complete Initial Pilot Test	February 1994
Interim Results Report	March 1994
Six Month Respiration Test	July 1994
Final Respiration Test	January 1995

7.0 POINTS OF CONTACT

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646 CES/CEVR
501 DeLeon Street, Suite 100
Eglin AFB, FL 32542-5101
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(904) 882-8908 (FAX)

Mr. Jay Baynes
1 SOCES/CEV
BLDG. 90137
304 Terry Avenue
Hurlburt Field, FL 32544-5260
(904) 884-4651
(904) 884-5724 (FAX)

Lt. Colonel Ross Miller/Mr. Marty Faile
AFCEE/ESR/ESCT
Brooks AFB, Texas 78235-5000
(210) 536-4331/(210) 536-4342

Need to update Address?

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Liverpool, New York 13088
(315) 451-9560 Fax.(315) 451-9570

Mr. Ola Awosika
Engineering-Science, Inc.
57 Executive Park South, NE, Suite 500
Atlanta, Georgia 30329
(404) 235-2371 Fax (404) 235 2500

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8.0 REFERENCES

Engineering-Science, Inc., 1981. *Installation Restoration Prgram - Phase I - Record Search, Hazardous Materials Disposal Sites, Eglin AFB, Florida.* USAF, Tyndall AFB, Florida.

Engineering-Science, Inc., 1988. *Installation Restoration Program - Phase II - Confirmation Quantification - Stage 2.* USAF, Brooks AFB, Texas.

Engineering-Science, Inc., 1992. Project Management Plan for AFCEE Bioventing, *Appendix D, Field Sampling Plan.* Denver, Colorado.

Engineering-Science, Inc. , 1992. *Installation Restoration Program - Phase II, Stage 3. Remedial Investigation/Feasibility Study, Eglin AFB, Forida.* USAF, Brooks AFB, Texas.. .

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, R. Frandt, 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Columbus, Ohio.

APPENDIX A

GENERIC HEALTH AND SAFETY PLAN

PROGRAM HEALTH AND SAFETY PLAN
FOR
BIOVENTING TEST INITIATIVE

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
ENVIRONMENTAL RESTORATION DIVISION (ESR)
BROOKS AIR FORCE BASE, TEXAS 78235-5000

USAF CONTRACT F33615-90-D-4014, DELIVERY ORDER 14

June 1992

Prepared by:

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900
Denver, Colorado 80290

Reviewed and Approved By:

	Name	Date
Project Manager	Doug Downey	29 Dec 92
Office H & S Representative	Timothy S Mustard	12/29/92

A7-15-5

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(CONTINUED)

SECTION 2

PROJECT DESCRIPTION AND SCOPE OF WORK

2.1 PROJECT DESCRIPTION

Work performed under this contract will remediate soils primarily contaminated with fuels using venting and bioremediation technologies. Sites will be located on Air Force installations across the United States and remediation activities will be performed under a variety of climatic, soil, and contaminant conditions.

2.2 SCOPE OF WORK

The objective of the bioventing program is to aid in remediating site soils. This scope of work was developed through evaluation of previous investigation results, current remediation efforts, and results of a bioventing pilot test at other Air Force sites.

The scope of work for this project includes construction and installation of the bioventing system, and operation, monitoring and maintenance of the system for one year. This project will include the following field activities: drilling and installation of vapor collection and monitoring wells; excavation of shallow trenches; assembly and wiring of mechanical/electrical components of venting/biodegradation systems; maintenance of the system; and periodic sampling and monitoring of soil vapors at the site.

SECTION 4

SITE-SPECIFIC EMPLOYEE TRAINING AND MEDICAL MONITORING REQUIREMENTS

The ES corporate health and safety manual is incorporated by reference (Engineering-Science, Inc., 1987). It presents general requirements for Engineering-Science employee training and medical monitoring. All field team members will have the 40-hour Occupational Safety and Health Administration (OSHA) training as specified in Title 29, Code of Federal Regulations Section 1910.120 (29 CFR 1910.120) and a current 8-hour annual refresher course. All field team members will be on appropriate and current medical monitoring programs. Listed below are additional health and safety training and medical monitoring requirements for this project.

4.1 ADDITIONAL SAFETY TRAINING REQUIREMENTS

All Engineering-Science team personnel engaged in site supervisory positions will have completed the 8-hour OSHA supervisory training as specified in 29 CFR 1910.120(e). All field team members must have site-specific training. Weekly safety briefings will be conducted if necessary.

4.2 ADDITIONAL MEDICAL MONITORING REQUIREMENTS

There are no additional medical monitoring requirements for bioventing sites on U.S. Air Force Bases under this contract.

TABLE 5.1
HEALTH AND PHYSICAL HAZARD AND RECOGNITION QUALITIES OF SITE CONTAMINANTS[a/]

Contaminant	PEL[b/] (ppm)	TLV[c/] (ppm)	IDLH[d/] (ppm)	Warning Conc.[e/] (ppm)	IP[f/] (eV)	Fire Hazard	Explosion Hazard	Comments
Benzene[g,h/]	1	10	3,000	4.68	9.24	Dangerous	Moderate	Eye and nose irritant. Chronic exposure has been linked to leukemia.
Ethylbenzene[g/]	100	100	2,000	0.2-200	8.76	Dangerous	Moderate	Eye and mucous membrane irritant. Can cause headache, narcosis, and coma following exposure to high concentrations.
Gasoline[i/]	300	300	--	<.01-10	--	Dangerous	Moderate	Avoid skin and eye contact.
Jet Fuel[j/]	500	300	10,000	0.08	--	Dangerous	Moderate	No exposure limits set. Long-term effects include liver, kidney, and CNS damage.
Toluene[g/]	100	100	2,000	0.2-4.0	8.8	Dangerous	Moderate	Fatigue, weakness, confusion, and headache.
Trichloroethane (TCE)[h/]	50	50	1,000	21.4-400	9.45	Dangerous	Moderate	Suspected carcinogen, narcotic anesthetic, eye irritant, causes nausea, vomitting, visual disturbances arrhythmias
Xylene[g/]	100	100	1,000	0.05-200	8.5	Moderate	Moderate	Dizziness, drowsiness, irritant and may cause vomitting and abdominal pains.

a/ Information summarized from Sax, 1979. Dangerous Properties of Industrial Materials, Fifth Edition; OSHA regulations contained in 29 CFR 1910.1000; EPA. 1983. Response Safety Decision-Making Workshop manual; American Conference of Governmental Industrial Hygienists (ACGIH). 1991-92 Threshold Limit Values; and National Institute for Occupational Safety and Health (NIOSH)/OSHA 1990. Pocket Guide to Chemical Hazards.

b/ PEL: Permissible Exposure Limit expressed as parts per million (ppm) unless otherwise indicated. OSHA limit as found in 29 CFR 1910.1000.

c/ TLV: Threshold Limit Value expressed as ppm unless otherwise indicated. From Plunkett, E.R., Handbook of Industrial Toxicology, 1976; or ACGIH 1991-92.

d/ IDLH: Immediately dangerous to life or health. Expressed as ppm unless otherwise indicated.

e/ Warning concentration is the odor threshold of the substance. Different sources listed different warning concentrations. When a range is given, use the highest concentration.

f/ IP - Ionization potential expressed in electron volts (eV).

g/ Volatile components of gasoline and jet fuel.

h/ Potential human carcinogen.

i/ Note: Primary constituent of concern in gasoline is Benzene. The OSHA PEL for Benzene is 1 ppm.

j/ Based on petroleum distillates (naphtha).

- During continual operations, onsite workers act as safety backup to each other. Offsite personnel provide emergency assistance.
- All field crew members should make use of all of their senses to alert themselves to potentially dangerous situations which they should avoid (e.g., presence of strong and irritating or nauseating odors).
- Field crew members will be familiar with the physical characteristics of investigations, including:
  - Wind direction in relation to contamination zones;
  - Accessibility to associates, equipment, and vehicles;
  - Communications;
  - Hot zone (areas of known or suspected contamination);
  - Site access; and
  - Nearest water sources.
- Personnel and equipment in a work area should be minimized, consistent with effective site operations.

In the event that any member of the field crew experiences any adverse effects or symptoms of exposure while on the scene, or that organic vapors and combustible vapors exceed the action limits, the entire field crew will immediately halt work and act according to the instructions provided by the SHSO.

The discovery of any condition that would suggest the existence of a situation more hazardous than anticipated will result in the evacuation of the field team and reevaluation of the hazard and the level of protection required.

In the event an accident occurs, the field supervisor is to complete an Accident Report Form. Follow-up action should be taken to correct the situation that caused the accident.

Electrical safety, fire safety, physical hazards, general emergency procedures, and specific procedures for handling personal injury and chemical exposure, are described in the following sections.

6.3 ELECTRICAL SAFETY

The equipment used in the bioventing system is electrically operated. Maintenance and day-to-day activities require personnel to handle and control this equipment. Unless safe work practices are strictly observed, serious injury or death can result.

Ordinary 120 volt (V) alternating current may be fatal. Extensive studies have shown that currents as low as 10 to 15 milliamps (mA) can cause loss of muscle control and that 12 V AC may, on good contact, cause injury. Therefore, all voltages should be considered dangerous. All electricity should be treated cautiously by trained personnel.

- When performing electrical work, even simply energizing a piece of equipment, observe "No Smoking" signs.
- When working around electrical equipment, keep your mind on the potential hazards at all times.

6.3.2 Holding and Locking Out Electrical Circuits

The most important safety requirement in electrical maintenance is to have and adhere to a good system for locking out electrical circuits when equipment is being repaired. Unexpected operation of electrical equipment that can be started by automatic or manual remote control may cause injuries to persons who happen to be close enough to be struck.

When motors or electrical equipment require repair, the circuit should be opened at the switch box, and the switch should be padlocked in the "OFF" position.

All personnel involved in maintenance work should be instructed in the following lockout procedure:

- Alert the affected personnel.
- Before starting work on an engine, motor line shaft, or other power transmission equipment, or power driven machine, make sure it cannot be set in motion without your permission.
- Place your own padlock on the control switch, lever, or valve, even though someone may have already locked the control. You will not be protected unless you put your own padlock on it.
- When through working at the end of your shift, remove your padlock; never permit someone else to remove it for you; and be sure you are not exposing another person to danger by removing your padlock.
- After repair, clear personnel from area BEFORE closing the breaker.

Further information concerning lockout/tag out procedures can be found in 54 CFR Part 169.

6.4 FIRE SAFETY

Jet fuel and possibly some solvents have been released into the soils at these sites and vapors escaping from the soils may be flammable or explosive (if in a confined space). Therefore, precautions should be taken when doing field work (drilling or system construction/installation) to ensure that combustible or explosive vapors have not accumulated or that an ignition source is not introduced into a flammable atmosphere.

OSHA standards for fire protection and prevention are contained in 29 CFR Subpart F, 1926.150 through 1926.154. Of particular concern on this site are:

- Proper storage of flammables;
- Adequate numbers and types of fire extinguishers;

- Sharp objects.

Site personnel will be instructed to look for potential safety hazards and immediately inform the site health and safety officer or the task manager about any new hazards. If the hazard cannot be immediately removed, actions must be taken to warn site workers about the hazard.

6.5.3 Excavation Activities

Prior to any excavation activity, the location, if any, of underground installations such as sewers, telephone, water, fuel, and electric lines must be determined. The walls and faces of all excavation in which personnel are exposed to danger from moving ground must be guarded by a shoring system, sloping of the ground, or by some other equivalent means.

Excavations (greater than 4 feet deep) must be inspected by a competent person, as defined in OSHA, after every rainstorm or other hazard increasing occurrence, and the protection against slides and wall collapse will be increased if necessary. All OSHA requirements concerning excavation activities, contained in 29 CFR 1926.651, must be followed.

6.5.4 Drilling Accidents

Hazards associated with drilling activities may occur from suspended loads dropping on employees, being caught behind a load and a stationary object, or being struck by counterweights. Accidents of this type are most likely to occur during drilling operations and can be prevented by the safe operation of drilling equipment, wearing protective equipment including a hard hat and safety boots, and the routine inspection of drilling equipment to identify unsafe conditions (e.g., frayed ropes).

6.5.5 Subsurface Hazards

Before any drilling or soil gas activity begins, efforts must be made to determine whether underground installations, (e.g., sewers, telephone, water, fuel, and electric lines) will be encountered and, if so, where such underground installations are located. Utility companies or the base engineer will be contacted by the field team leader prior to commencing drilling or soil gas operations and the necessary clearances obtained using Air Force Form 103.

6.5.6 Electrical Line Clearance and Thunderstorms

Extra precautions will be exercised when drilling near overhead electrical lines. The minimum clearance between overhead electrical lines of 50 kilovolts (kV) or less and the drill rig is 10 feet. For lines rated over 50 kV, the minimum clearance between the lines and any part of the rig is 10 feet plus 0.4 inches for each kV over 50 kV. Drilling operations must cease during thunderstorms.

The SHSO will provide onsite surveillance of the drilling subcontractor to ensure that personnel meet these requirements. If deficiencies are noted, work will be stopped and corrective actions implemented. Reports of health and safety deficiencies and the corrective actions taken will be forwarded to the installation manager by the SHSO.

- Precautions should be taken to avoid exposure of other individuals to the chemical.
- If the chemical is on the individual's clothing, the clothing should be removed if it is safe to do so.
- Administer first aid and transport the victim to the nearest medical facility, if necessary.

6.9 EMERGENCY SITE SECURITY AND CONTROL

For this project, the installation manager (or designated representative) must know who is onsite and who is in the work area. Personnel access into the work area should be controlled. In an emergency situation, only necessary rescue and response personnel should be allowed into the exclusion zone.

6.10 PROCEDURES FOR EMERGENCY MEDICAL TREATMENT AND FIRST AID

6.10.1 Chemical Exposure

In the event of chemical exposure (skin contact, inhalation, ingestion) the following procedures should be implemented:

- Another team member (buddy) should assist or remove the individual from the immediate area of contamination to an upwind location if it is safe to do so.
- Precautions should be taken to avoid exposure of other individuals to the chemical.
- If the chemical is on the individual's clothing, the clothing should be removed if it is safe to do so.
- If the chemical has contacted the skin, the skin should be washed with copious amounts of water, preferably under a shower.
- In case of eye contact, an emergency eye wash should be used. Eyes should be washed for at least 15 minutes.
- If necessary, the victim should be transported to the nearest hospital or medical center. If necessary, an ambulance should be called to transport the victim.

6.10.2 Personal Injury

In the event of personal injury:

- Field team members trained in first aid can administer treatment to an injured worker.
- The victim should be transported to the nearest hospital or medical center. If necessary, an ambulance should be called to transport the victim.
- The field supervisor is responsible for the completion of an Accident Report Form.

SECTION 7

LEVELS OF PROTECTION AND PERSONAL PROTECTIVE EQUIPMENT REQUIRED FOR SITE ACTIVITIES

7.1 PERSONAL PROTECTIVE EQUIPMENT

Levels of protection and PPE required for site activities are based upon the risk of exposure to chemical contaminants (fuel hydrocarbons, TCE, etc.). The personal protection level prescribed for these projects is OSHA Level D with a contingency for the use of OSHA modified Level D as well as Level C or Level B. PPE will be required when handling contaminated samples, working with potentially contaminated materials, during construction or installation of bioventing systems.

The Level D modified personnel protective ensembles will be required when personnel are handling contaminated samples or working with potentially contaminated equipment during construction or installation of the bioventing system. Such Level D modified PPE could typically include:

- Vinyl or latex inner gloves;
- Neoprene or "Silver Shield" outer gloves;
- Leather or rubber safety boots (construction or installation only);
- Hard Hat (construction or installation only); and
- Disposable coveralls (construction or installation only).

The following is required for construction activities involving soil excavation activities and suggested for all site activities:

- Either an OVA, HNu, or Photovac TIP or Micro TIP;
- Full size trash bags for decontamination; and
- Plastic drop cloth for decontamination.

7.2 EQUIPMENT NEEDS

Each field team shall have the following items readily available:

- Copy of site health and safety plan including a separate list of emergency contacts;

- Heat exhaustion: Caused by increased stress on various organs to meet increased demands to cool the body. Signs include shallow breathing; pale, cool, moist skin; profuse sweating; and dizziness and lassitude.
- Heat stroke: The most severe form of heat stress. Body must be cooled immediately to prevent severe injury and/or death. Signs include red, hot, dry skin; no perspiration; nausea; dizziness and confusion; strong, rapid pulse; and possibly coma. Medical help must be obtained immediately.

7.3.3 Heat-Stress Monitoring

Monitoring of personnel wearing impervious clothing will begin when the ambient temperature is 70°F or above. Table 7.1 presents the suggested frequency for such monitoring. Monitoring frequency will increase as the ambient temperature increases or as slow recovery rates are observed. Heat-stress monitoring will be performed by a person with a current first-aid certification who is trained to recognize heat-stress symptoms. For monitoring the body's recuperative abilities from excess heat, one or more of the techniques listed below will be used. Other methods for determining heat-stress monitoring, such as the wet bulb globe temperature index from the ACGIH TLV booklet may be used.

To monitor the worker, measure:

- Heart rate: Count the radial pulse during a 30-second period as early as possible during the rest period.
  - If the heart rate exceeds 110 beats per minute at the beginning of the rest period, the next work cycle will be shortened by one-third and the rest period will remain the same.
  - If the heart rate still exceeds 110 beats per minute at the next rest period, the following work cycle will be reduced by one third.
- Oral temperature: Use a clinical thermometer (3 minutes under the tongue) or similar device to measure the oral temperature at the end of the work period (before drinking).
  - If oral temperature exceeds 99.6°F (37.6°C), the next work cycle will be reduced by one-third without changing the rest period.
  - If oral temperature still exceeds 99.6°F (37.6°C) at the beginning of the next rest period, the following cycle will be reduced by one-third.
  - No worker will be permitted to wear a semipermeable or impermeable garment when oral temperature exceeds 100.6°F (38.1°C).

SECTION 8

FREQUENCY AND TYPES OF AIR MONITORING

Air monitoring will be used to identify and quantify airborne levels of hazardous substances. Periodic monitoring is required during on site activities. The types of monitoring and equipment to be used are as follows:

Type of Equipment	Minimum Calibration Frequency	Parameter(s) to be Measured	Minimum Sampling Frequency	Sampling Locations
PID-	1/day	Organic Vapors	▪ 4/hr or each 5-foot intervals (while disturbing or drilling into soils) ▪ 1/hour when working near soil vapor extraction unit	▪ Breathing Zone
Sensidyne® or Draeger® Tubes	-	Benzene	▪ When PID exceeds 1 ppm	▪ Breathing Zone

During operations that disturb site soils, a photoionization detector (such as an HNu®, Photovac TIP®, or MicroTIP®) should be used to measure ambient air concentrations in the worker breathing zone and to screen split spoon samples which will be taken at five-foot intervals. A concentration of 1 ppm above background in the breathing zone will necessitate evacuation until the area is well ventilated (based on the exposure limit for benzene).

If and when the PID or Microtip® exceeds 1 ppm for a one minute period, site workers will move upwind and don respirators. The SHSO will then reenter the "hot" zone with a benzene sensitive Sensidyne® tube and PID. If the benzene concentration is less than 1 ppm and the PID is less than 100 ppm the work site can be reentered without a respirator (Note: by locating yourselves upwind of drilling operations much of this procedure can be avoided). If benzene concentrations are

SECTION 9

SITE CONTROL MEASURES

The following site control measures will be followed in order to minimize potential contamination of workers, protect the public from potential site hazards, and to control access to the sites. Site control involves the physical arrangement and control of the operation zones and the methods for removing contaminants from workers and equipment. The first aspect, site organization, is discussed in this section. The second aspect, decontamination, is considered in the next section.

9.1 SITE ORGANIZATION/OPERATION ZONES

Any time respirators are worn, the following operation zones will be established on the site or around a particular site feature (such as the drill rig, or bioventing system).

- Exclusion Zone (Contamination Zone),
- Contamination Reduction Zone, and
- Support Zone.

If protective clothing, such as gloves and/or Tyvek® suits are worn but respirators are not worn (Level D-modified), the field crew will establish a decontamination area to avoid spreading contaminants offsite. The field team leader and/or SHSO will be responsible for establishing the size and distance between zones at the site or around the site feature. Considerable judgement is required to assure safe working distances for each zone are balanced against practical work considerations.

9.1.1 Exclusion Zone (EZ) (Contamination Zone)

The EZ includes the areas where active investigation or cleanup operations take place. Within the EZ, prescribed levels of PPE must be worn by all personnel. The hotline, or EZ boundary, is initially established based upon the presence of actual wastes or apparent spilled material, or through air monitoring, and is placed around all physical indicators of hazardous substances. The hotline may be readjusted based upon subsequent observations and measurements. This boundary should be physically secured and posted or well-defined by physical and geographic boundaries.

Under some circumstances, the EZ may be subdivided into zones based upon environmental measurements or expected onsite work conditions.

- No smoking, eating, drinking;
- No matches/lighters in the zone;.
- Check in/check out at access control points;
- Use the buddy system;
- Wear appropriate PPE;
- Avoid walking through puddles or stained soil;
- Discovery of unusual or unexpected conditions will result in immediate evaluation and reassessment of site conditions and health and safety practices;
- Conduct safety briefings prior to onsite work;
- Conduct daily/weekly safety meetings as necessary; and
- Take precautions to reduce injuries from heavy equipment and other tools.

The following guideleines will also be followed while working onsite:

- Heavy Equipment - Only qualified operators will be allowed to operate heavy equipment. Subcontractors will be required to use the safe work guidelines included in the OSHA General Industry (29 CFR 1910) and Construction Industry (29 CFR 1926) Standards.
- Electrical Equipment - As outlined in Section 6.3.1
- Machine Guarding - All machinery onsite will be properly guarded to prevent contact with rotating shafts, blades or gears.
- Illumination - Work areas will be lighted beyond the minimum requirements of 29 CFR 1910.120
- Engineering Controls - In the event that the project requires additional provisions to safeguard the public and onsite personnel.

necessary prior to the start of the drilling operation, between borehole locations, and before the drill rig leaves the project site. All sampling equipment will be decontaminated prior to use, between samples, and between sampling locations. Sampling equipment should be thoroughly washed with detergent, followed by clean water rinse, solvent (methanol) rinse, and a distilled water rinse. Adequate time will be allowed for solvent evaporation.

wait a few seconds for the readings to stabilize. Check the battery charge and the alarms before using the instrument.

To calibrate the instrument with span gas, attach the flow regulator to the calibration gas cylinder. Fill a 3-liter Tedlar bag with calibration gas. Connect the instrument to the Tedlar bag using Tygon tubing and wait for the readings to stabilize. Using a small jeweler's screwdriver, adjust the span gas pot on the side of the instrument to obtain a steady reading which corresponds with the calibration gas concentration. Remove the calibration lines and let the instrument run for a full minute to flush out any excess span gas. Check readings; the combustible sensor should now be reading zero in fresh air.

11.4 SENSIDYNE® OR DRAEGER® COLORIMETRIC GAS ANALYSIS TUBES (BENZENE SPECIFIC)

Drăger® tubes can be used to give an instantaneous reading of various organic compounds. Their aim is to determine very small concentrations of a compound in the shortest amount of time. To sample with a Dräger tube use the Dräger® or Sensidyne® bellows pump and select the appropriate tube (for example, a tube marked benzene to look for benzene). Break off both ends on the pump's break-off plate. Insert the tube into the pump head (the tube should be inserted with the arrow pointing towards the pump). There is a given number of suction strokes for each tube/compound. Each box of tubes will have instructions for how many suction strokes are required for that compound.

APPENDIX A

EMERGENCY CONTACTS

In the event of any situation or unplanned occurrence requiring assistance, the appropriate contact(s) should be made from a list similar to this which will be prepared in the health and safety plan addenda. For emergency situations, telephone or radio contact should be made with the site point of contact or site emergency personnel who will then contact the appropriate response teams.

Contingency Contacts	Phone Number
Nearest phone located at the work site	____________
Base Fire Department	____________
Site Contact	____________
Site Medical Services	____________
Site Emergency Number	____________
Security Police	____________
Medical Emergency	
Hospital Name	____________
Hospital Phone Number	____________
Ambulance Service (Also Police)	____________
Airlift helicopter	____________

Directions or Map to the Hospital

ES Contacts	
ES Project Manager Doug Downey	(303) 831-8100 (w) (303) 670-0512 (h)
ES Health and Safety Manager Timothy Mustard	(303) 831-8100 (w) (303) 450-9778 (h)
Corporate Health and Safety Manager Edward Grunwald	(404) 325-0770 (w)

APPENDIX B

SITE /BASE SPECIFIC TRAINING RECORD

On this date __________ the following individuals were provided site specific training in accordance with OSHA regulations contained in 29 CFR 1910.120 (e). These individuals have also read and are familiar with the contents of the site specific health and safety plan.

Name (print) Employee No. Signature

1.____

2.____

3.____

4.____

5.____

PLAN ACCEPTANCE FORM
PROJECT HEALTH AND SAFETY PLAN

Instructions: This form is to be completed by each person to work on the subject project work site and returned to the safety manager.

I have read and agree to abide by the contents of the Health and Safety Plan for the following project:

____

____

____
Signed

____
Date

RETURN TO:

Office of Health and
Safety Representative
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290

SCBA LOG

SITE:

LOCATION:

DATES OF INVESTIGATION:

User	Date of Use	SCBA#	Satisfactory (Yes/No)	Check Out Initials	Date Cleaned

SCBA Performance Comments:

Project H&S Officer
or
ES Project Manager

Date

Return to Office of Health and Safety Representative
at the completion of field activities.

AIR PURIFYING
RESPIRATOR LOG

SITE:

LOCATION:

DATES OF INVESTIGATION:

User	Date of Use	Cleaned and Inspected Prior To Use (Initials)	Cartridges Changed Prior to Use (Yes, No, N/A)	Total Hours on Cartridge

SCBA Performance Comments:

Project H&S Officer
or
ES Project Manager

Date

Return to Office of Health and Safety Representative
at the completion of field activities.

DAILY HEALTH AND SAFETY REPORT

This form is to be completed by the ES site Health and Safety Officer or Resident Construction Manager. The aforementioned shall return the original form to the office Health and Safety Representative and place a copy in the site Health and Safety file.

Name____________________ Project Name____________________
Date____________________ Project Number____________________

1) Have all field team members reviewed the site H&S Plan? Yes____ No____

   If not, explain why and corrective actions taken:________________________

   ____

2) Are Plan Acceptance Forms on file for all field team members? Yes___ No____

   (If not, obtain form and forward to Office H&S Representative).

3) Is at least one copy of the site H&S Plan present on-site for employee review?

   Yes____ No____
   (If not, obtain copy immediately andinform employees of its location).

4) Are all field team members on current and appropriate medical monitoring and have they had the required 40-hour/8-hour training within the past year?

   Yes____ No_____
   If not, explain why and corrective actions taken:________________________

   ____

5) Have all field team members received on-site H&S training? Yes____ No___

   If yes, describe frequency: Initial_____Daily_____Weekly____
   (If not, perform required training before allowing employee(s) to continue working on-site).

6) Provide the following information:

Task	Employee Name (by Task)	Level of Respiratory Protection (for each employee)	Comments

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7) Was heat stress monitoring performed today? Yes_____ No_____
If yes, was it documented?_____
If no, explain:_____

8) Was personal air monitoring conducted today? Yes_____ No_____
If yes, describe:_____
If no, explain:_____

9) Describe other air monitoring procedures used today:_____

10) Were site work zones established today? Yes_____ No_____
If not, explain:_____

11) Describe personal decontamination procedures used today:_____

12) Did any accidents occur today? Yes_____ No_____
If yes, describe:_____

13) Comments:_____

Return this report to the Office Health and Safety Representative.

ACCIDENT REPORT FORM

Project:______________________________

EMPLOYER

1. Name____

2. Mail Address______________________________________
(No. and Street) (City or Town) (State)

3. Location, if different from mail address___________________________
____

INJURED OR ILL EMPLOYEE

4. Name____________________Social Security Number______________
(First) (Middle) (Last)

5. Home Address____
(No. and Street) (City or Town) (State)

6. Age____________7. Sex: Male______ Female__________(Check one)

8. Occupation____
(Specific job title, not the specific activity s/he was performing at time of injury).

9. Department____
(Enter name of department in which injured persons is employed, even though s/he may have been temporarily working in another department at the time of injury).

THE ACCIDENT OR EXPOSURE TO OCCUPATIONAL ILLNESS

10. Place of accident or exposure_______________________________
(No. and street) (City or Town) (State)

11. Was place of accident or exposure on employer's premises? (Yes/No)

12. What was the employee doing when injured?_______________________
____
____

(Be specific - If he was using tools or equipment or handling material, name and tell what he was doing).

ACCIDENT REPORT FORM
(CONTINUED)

13. How did the accident occur?____________________________________

(Describe fully the events which resulted in teh injury or occupational illness. Tell what happened and how. Name any objects or substances involved. Give details on all factors which led to accident. Use separate sheet for additional space.)

14. Time of accident:____________________________

15. WITNESS TO ACCIDENT

(Name)	(Affiliation)	(Phone No.)
__________	__________	__________
__________	__________	__________
__________	__________	__________

OCCUPATIONAL INJURY OR OCCUPATIONAL ILLNESS

16. Describe the injury or illness in detail and indicate the part of body affects:______

17. Name the object or substance which directly injured the employee. (For example, the machine or thing or struck against him; the vapor or poison he inhaled or swallowed; the chemical or radiation which irritated his skin; or in cases of strains, hernias, etc., the thing he was lifting, pulling etc.)

18. Date of injury or initial diagnosis of occupational illness__________________
Date

19. Did employee die?__________________(Yes or No)

OTHER

20. Name and address of physician__________________________________

21. If hospitalized, name and address of hospital_________________________

Date of report__________________ Prepared by____________

Official position______________________

ADDENDUM TO THE PROGRAM HEALTH AND SAFETY PLAN FOR THE BIOVENTING TEST INITIATIVE

ADDENDUM TO THE PROGRAM HEALTH AND SAFETY PLAN FOR THE BIOVENTING TEST INITIATIVE

BASE NAME: EGLIN AFB, FL | **JOB #DE268.43.02**

Installation Manager:	**Ola Awosika**
Site Health and Safety Officer:	**Tom Kessler**
Site Contact - U.S. Air Force Installation:	**Mr. John Krishack** **Chief, Installation Restoration Program** **646, CES/CEVR** **501, Deleon St., Suite 100** **Eglin AFB, FL 32542-5101** **(904) 882-2878**

REVIEWED AND APPROVED BY:

Project Manager: ______________________ ______________
Name Date

Program H&S Manager: ______________________ ______________
Name Date

1.0 INTRODUCTION

This addendum modifies the existing Program Health and Safety Plan for the Bioventing Test Initiative, for conducting bioventing pilot tests at United States Air Force facilities under contract number F33615-90-D-4014.

This addendum outlines the site-specific requirements and provides site-specific information for work which will be conducted at three sites at Eglin AFB, Florida. The Sites of interest for this bioventing Pilot Study are A-20 Radar Facility (Site SS-01), Hurlburt Field Fire Training Area (Site FT-39), and Eglin Main Old Fire Training Area (Site FT-28), Eglin AFB, Florida

Two additional documents providing information regarding activities to be performed on this site are the Protocol Document and the Site-specific Bioventing Test Work Plan for Air Force Plant 6.

Included or referenced in this addendum are site-specific descriptions, history and site-specific activities; hazard evaluation of known or suspected chemicals; personal protective equipment (PPE); personnel decontamination procedures; site-specific training and medical monitoring requirements; air monitoring; site control procedures; employee exposure monitoring; and emergency response procedures.

2.0 SITE DESCRIPTION, HISTORY, AND SITE-SPECIFIC ACTIVITIES

The site description, history, and site-specific activities to be performed at this site are outlined in the site-specific work plan entitled *Bioventing Test Work Plan for the Vioventing Test Work Plan for A-20 Radar Facility (Site SS-01), Hurlburt Field Fire Training Area (Site FT-39), and Eglin Main Old Fire Training Area (Site FT-28), Eglin AFB, Florida*

3.0 SITE-SPECIFIC EMPLOYEE TRAINING AND MEDICAL MONITORING REQUIREMENTS

See Section 4 of the program health and safety plan for guidance.

4.0 HAZARD EVALUATION

4.1 Chemical Hazards

General hazards are addressed in the program health and safety plan. Site-specific hazards are identified below.

Chemicals known or suspected to occur at this site include hydrocarbon fuel components benzene, toluene, ethylbenzene, and xylenes (BTEX), total and petroleum hydrocarbons.

Health hazard qualities for these compounds are presented in Table 5.1 of the program health and safety plan.

4.2 Physical Hazards

Potential physical hazards at this site include risks associated with the installation/operation of bioventing equipment and the hazards from working in or around moving equipment (such as drill rigs, motor vehicles, etc.).

Protection standards for physical hazards are contained in Section 7 of the program health and safety plan.

5.0 AIR MONITORING

During operations that disturb site soils, a hydrocarbon detector (HNU\ or equivalent) will be used to measure ambient air concentrations in the worker breathing zone. Flammable vapor monitoring will be conducted if potentially flammable atmospheres occur. See Sections 8 and 11 of the program health and safety plan for specific guidance.

6.0 SITE CONTROL PROCEDURES

Site control measures will be followed in order to minimize potential contamination of workers, protect the public from potential site hazards, and control access to the sites. Site control involves the physical arrangement and control of the operation zones and the methods for removing contaminants from workers and equipment. See Section 9 of the program health and safety plan for guidance.

Specific site control procedures at this site will include those outlined in the program health and safety plan.

7.0 PERSONAL PROTECTIVE EQUIPMENT

It is anticipated that Level D respiratory protection with a contingency for the use of Level C&B will be used at this site. Additional guidelines for the selection of respiratory protection at this site are contingent upon the discovery of benzene while performing site activities. Site crews will assess the need for respiratory protection or PPE as applicable.

Protective clothing to be used at this site includes:

Hard hats	
Suits (Tyvek or Saranex)	Respirator not anticipated
Inner gloves (Latex or Vinyl)	Cartridges
Outer gloves (Nitrile or Neoprene)	Other
Boots (Safety boots with latex boot covers)	

8.0 PERSONNEL DECONTAMINATION PROCEDURES

See Section 10 of the program health and safety plan for guidance.

9.0 EMPLOYEE EXPOSURE MONITORING

Employee exposure monitoring will be conducted on this site in accordance with federal OSHA Standards (29 CFR 1910) and the program health and safety plan.

10.0 EMERGENCY RESPONSE PLAN

10.1 Safe Distances and Places of Refuge

Prior to initiation of field activities, the field crew shall decide on safe distances to retreat to and a place of refuge in the event of an emergency. This information shall be provided in weekly site-specific safety briefings. All other guidelines established in the program health and safety plan for emergency planning, training, recognition, etc. shall be followed.

10.2 Emergency Information

Hospital	Eglin AFB Hospital
Address	Base Hospital, Bldg. 2825, Boatner Road Eglin AFB, Florida
Phone	(904) 882-2333

Description of the route to the hospital.

A Map outlining the best route to the hospital is shown in Figure 10.1 and Table A-1.

Other Emergency Numbers:

Fire Department	(904) 882-5856
Security Police	(904) 882-2000
Ambulance	(904) 882-1110

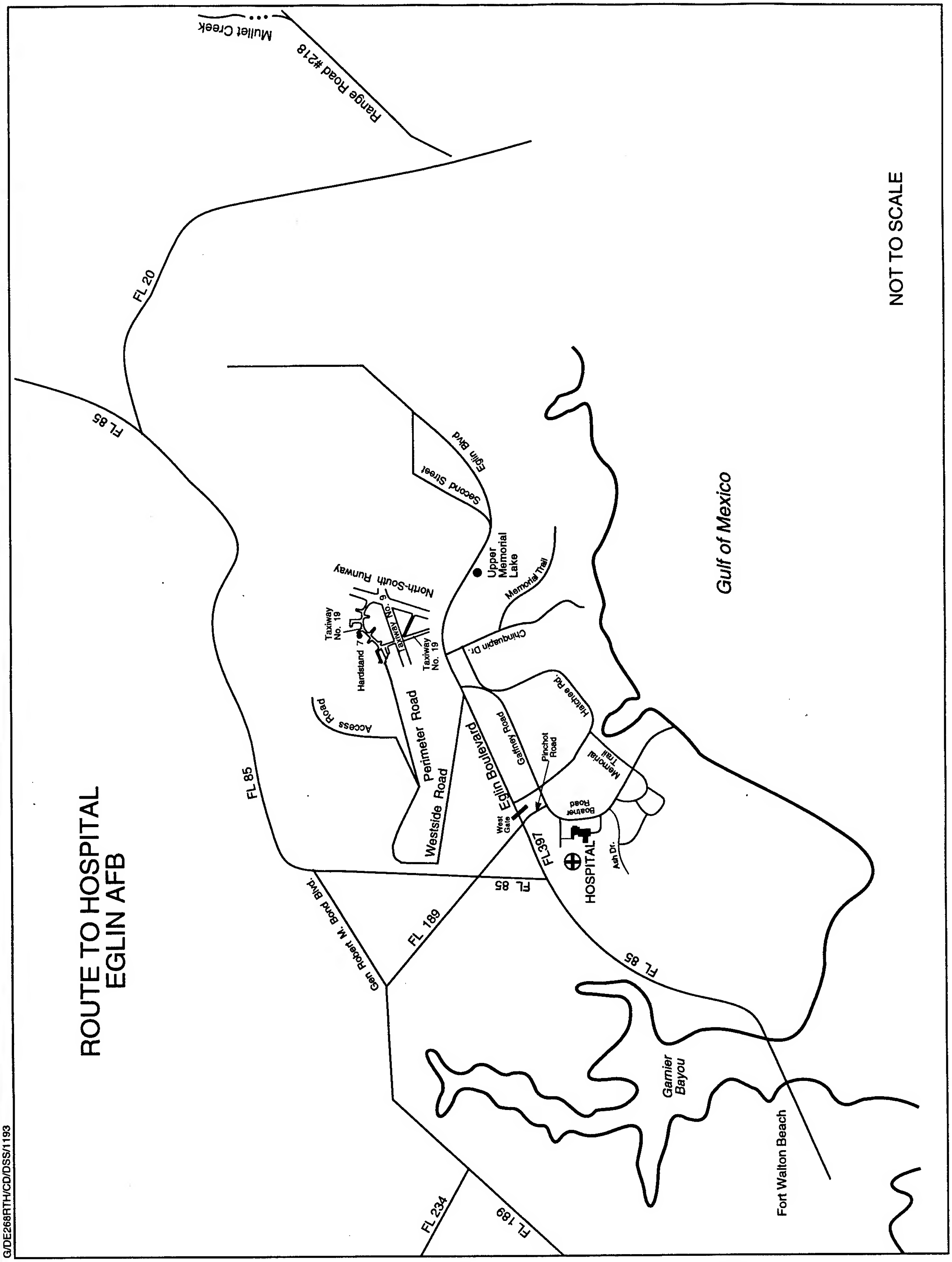
Program Health and Safety Manager:

Tim Mustard work: (303) 831-8100
home: (303) 450-9778

Project Manager:

Doug Downey work: (303) 831-8100
home: (303) 670-0512

ROUTE TO HOSPITAL EGLIN AFB



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ES ENGINEERING-SCIENCE

TABLE A-1

**EGLIN AIR FORCE BASE
DIRECTIONS TO HOSPITAL**

FROM THE HURLBURT FIELD SITE:	Follow Red Horse Road east to Hamby Place. go south on Hamby to Tully Street (1500 feet). south on Tully to Cody Avenue (approximately 100 feet) to Main Gate).
AT HURLBURT GATE:	Left (east) on State Route 98. Right at the gate, then take the first left and proceed about a mile to state route 98. go left on state route 98.
FROM A-20 RADAR SITE:	Right at the gate, then take the first left and proceed about a mile to state route 98. go left on state route 98.
FROM EGLIN SITE (FT-28):	West on Second Street to Eglin Boulevard (follow approximately 3 miles west). Take Hatchee Raod (south) just prior to West Gate. Right on Boatner Road into hospital parking.
	Follow access road south to Perimeter Road (go right- west). Follow around runways to West Side Road (left). Follow 1.5 miles to Eglin Boulevard (turn right). Take Hatchee Road as described above.

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APPENDIX B

QUALITY ASSURANCE PROJECT PLAN

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APPENDIX B
QUALITY ASSURANCE PROJECT PLAN

B.1 PROJECT DESCRIPTION AND QUALITY ASSURANCE OBJECTIVES

B.1.1 Introduction

This Quality Assurance Project Plan (QAPP) is prepared for the AFCEE Bioventing Pilot Tests at 38 Air Force Bases nationwide. The QAPP follows the procedures as outlined in the standardized ES Quality Assurance Policy Manual. The primary references for this QAPP are the *Test Plan and Technical Protocol for a Field Treatability Test* (Protocol Document) for bioventing and the *Handbook to Support the Installation Restoration Program (IRP) Statements of Work, Volume I, Remedial Investigation/Feasibility Studies (RI/FS).* Because the purpose of these tests is to determine the feasibility of using the bioventing method for different site conditions, and not for RI/FS work, this QAPP uses the IRP Handbook for guidance but does not rigorously follow its formats and requirements.

The purpose of the quality assurance program is to ensure that the quality standards required to meet the project objectives are followed. The objective of the QAPP is to describe the procedures necessary to demonstrate that field testing, sample acquisition and analysis, review, verification, documentation, and reporting are performed to the quality standards outlined.

B.1.2 Project Description

See Project Description of the Project Management Plan AFCEE Bioventing Pilot Tests (PMP), Section 1.

B.1.3 Quality Assurance Objectives

The primary objective of the Quality Assurance/Quality Control (QA/QC) program is to ensure that the procedures followed and data obtained during the course of the project are adequate to determine the feasibility of using the bioventing methods for soil remediation under a variety of conditions. Specific objectives of the QA/QC program include the following:

- To ensure the use of proper investigative procedures and equipment in the field and the analytical laboratory;

- To specify the responsibilities of personnel included in the QA/QC program and how the program will be implemented; and
- To maintain a high level of quality during the field testing, data analysis, and report writing phases of the project.

B.2 ORGANIZATION AND STAFFING

The Organization and Staff responsibilities, including QA/QC responsibilities, are described in the PMP, Section 3.

B.3 LABORATORY TESTING QUALITY ASSURANCE OBJECTIVES FOR DATA MEASUREMENT

The quality assurance objectives for all laboratory analyses include considerations of precision, accuracy, completeness, representativeness, and comparability.

B.3.1 Precision

The precision of a measurement is an expression of mutual agreement of multiple measurement values of the same property conducted under prescribed similar conditions. Precision is evaluated most directly by recording and comparing multiple measurements of the same parameter on the same exact sample under the same conditions.

For laboratory analyses precision is expressed in terms of Relative Percent Difference (RPD). The RPD is calculated as follows:

$$\frac{\text{RPD} = (x_1 - x_2)\ 100}{(x_1+x_2)/2}$$

where:

x_1 = analyte concentration of first duplicate; and

x_2 = analyte concentration of second duplicate.

Acceptable levels of precision will vary according to the sample matrix, the specific analytical method, and the analytical concentration relative to the method detection limit. Replicate standards and/or spiked samples will be used to estimate the precision of 5 percent (1 in 20) of the analytical test procedures for a known matrix. Table B.1 shows the precision required for each analysis.

B.3.2 Accuracy

The term accuracy refers to the correctness of the value obtained from analysis of a sample, and is determined by analyzing a sample and its corresponding matrix spike sample. Accuracy is expressed as Percentage Recovery (PR) and is calculated using the following formula:

TABLE B.1

Sample Analysis Type, Number, Container, Method, Preservative, Holding Time, Reporting Units and Limits, and QA Objectives

SAMPLE MEDIUM	LABORATORY ANALYSIS TYPE Parameter	APPROXIMATE NUMBER SOIL SAMPLES BY SITE		SAMPLE CONTAINER			Analytical Method	Preservative	Holding Time	Holding Time After Leaching	Reporting Units	Method Reporting Limits	Precision a/ (%)	Accuracy b/ (%)	Completeness c/ (%)
		INITIAL	FINAL	NUMBER	SIZE	TYPE									
SOIL	BERKELEY	3	0	1	4 OUNCE	GLASS		None							
	INORGANIC														
	pH						SW9045		None	ASAP d/	pH units	0.05	20	75	90
	Alkalinity						A403		None	14 Days	mg/kg e/ as CaCO3	50 mg/kg	20	75	90
	Iron, Total						SW7380		None	6 Months	mg/kg	5.4 mg/kg	20	75	90
	Soil Moisture Content						SW846		14 Days	NA f/	% by weight	0.1%	20	75	90
	ORGANIC	3	3	1	4 OUNCE	3" DIA. SHELBY TUBE		Hold at 4 C							
	Benzene						SW8020		14 Days	NA	µg/kg g/	0.6 µg/kg	20	75	90
	Toluene						SW8020		14 Days	NA	µg/kg	0.7 µg/kg	20	75	90
	Ethyl Benzene						SW8020		14 Days	NA	µg/kg	0.5 µg/kg	20	75	90
	Xylenes (total)						SW8020		14 Days	NA	µg/kg	0.9 µg/kg	20	75	90
	TRPH h/						E418.1		14 Days	NA	mg/kg	10 mg/kg	20	75	90
	SEQUOIA ANALYTICAL	3	0	1	16 OUNCE	GLASS		None							
	INORGANIC														
	Total Kjeldahl Nitrogen						E351.2		28 Days	NA	mg/kg	1.0 mg/kg	20	75	90
	Total Phosphate						E365.3		28 Days	NA	mg/kg	1.0 mg/kg	20	75	90
	PHYSICAL														
	Soil Classification						Unified Classification Method		NA	NA	U.S. Standard Units	NA	20	75	90
AIR	AIR TOXICS	3	3	1	1 LITER	SUMMA(R) CANNISTER	TO-3(EPA)	None Do Not Chill	None	NA					
	ORGANIC														
	Benzene										ppmv, µg/L i/	0.001, 0.003	20	75	90
	Toluene										ppmv, µg/L	0.001, 0.004	20	75	90
	Ethyl Benzene										ppmv, µg/L	0.001, 0.004	20	75	90
	Xylenes (total)										ppmv, µg/L	0.001, 0.004	20	75	90
	TVH j/										ppmv, µg/L	0.01, 0.04	20	75	90

NOTES:
a/ Precision – Expressed as relative percent difference (RPD) of analytical results unless otherwise noted.
b/ Accuracy – Expressed as percentage recovery (PR).
c/ Completeness – Valid data percentage of total test results.
d/ ASAP – As soon as possible.
e/ NA – Not applicable.
f/ mg/kg – milligrams per kilogram.
g/ µg/kg – micrograms per kilogram.
h/ TRPH – total recoverable petroleum hydrocarbons.
i/ ppmv – parts per million per volume, µg/L – micrograms per liter.
j/ TVH – total volatile hydrocarbons.

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$$PR = \frac{(A-B)}{C} X100$$

where:

A = spiked sample result (SSR);

B = sample result (SR); and

C = spike added (SA).

The degree of accuracy and the recovery of analyte to be expected for the analysis of QA samples and spiked samples is dependent upon the matrix, method of analysis, and compound or element being determined. The concentration of the analyte relative to the detection limit is also a major factor in determining the accuracy of the measurement. The practical quantitation level for most analyses is generally stated in the analytical method. Certified standards and/or spiked samples will be used to estimate analyte recovery for each test procedure for a known matrix. The accuracy of Gas Chromatography (GC) analyses is compound- and matrix-dependent. Thus matrix spike recovery is used to determine the effect of the matrix, and a laboratory control sample is used to determine accuracy of the analyses. The recovery of analytes in a soil matrix is often lower than that obtainable for liquid matrices. As for precision, replicate standards and/or spiked samples will be used to estimate the accuracy of 5 percent (1 in 20) of analytical test procedures for a known matrix.

B.3.3 Completeness

The completeness of the data is the amount of valid data obtained from the measurement system (field and laboratory) versus the amount of data expected from the system. At the end of each sampling event, an assessment of the completeness of data will be performed and, if any sample omissions are apparent, an attempt will be made to resample if feasible. Resampling for laboratory analyses is not feasible, therefore, it is critical that holding times are met and that the laboratory inform the deputy project manager if any containers were broken during shipping. In addition, data completeness will be assessed prior to the preparation of data reports.

B.3.4 Representativeness

Samples taken must be representative of the population. To assess the representativeness of the samples, some samples will be collected in duplicate. Comparisons of the results from the original sample and its field duplicate will allow for an evaluation of the representativeness of the samples.

B.3.5 Comparability

Where appropriate, the results of analyses obtained may be compared with the results obtained in previous studies. Consistency in the acquisition, handling, and analysis of samples by USEPA-recommended procedures is necessary in order that the results may be compared. To this end, standard solutions and materials used in calibrating field and laboratory analytical instruments must be traceable to National

Bureau of Standards (NBS) or EPA standards, and published analytical methods will be followed. Any deviations from the specified analytical protocol will be documented by the laboratory.

B.4 SAMPLE HANDLING, SAMPLE RECEIPT

B.4.1 Sample Handling, Packaging, and Shipment

B.4.1.1 Sample Containers

Laboratory samples will be placed in pre-cleaned glass bottles, precleaned Shelby Tubes, and evacuated SUMMA® canisters as listed on Table B.1. The samples will be carefully packed for shipment. The pre-cleaned bottles, brass tubes, and SUMMA® canisters will be obtained from the analytical laboratory. If necessary, individual sample bottles will be wrapped in bubble pack to prevent breakage during transport to the lab. The bottles will be placed into insulated shipping coolers with a plastic bag of ice. A Chain-of-Custody Record describing the contents of the cooler will be placed in a sealed plastic bag and taped to the upper lid of the cooler. When coolers are delivered to the shipping company, they will be taped shut with security labels taped over opposite ends of the lid.

B.4.1.2 Sample Sealing and Labeling

Laboratory sample containers will be sealed with a custody seal. See Figure B.1 for a custody seal. Also on Figure B.1 is a sample label. The label will include the sample numbers assigned according to the sample numbering system.

B.4.1.3 Sample Numbering System

Each laboratory sample will be assigned a unique sample identification number that describes where the sample was collected. Each number will consist of a group of letters and numbers, separated by hyphens. The sample numbering system to be used on this project is presented on Table B.2.

B.4.1.4 Preservatives and Holding Times

After samples have been taken, they will be delivered to the laboratory for analysis as soon as possible after collection in order to ensure that the most reliable and accurate answers will be obtained as a result of the analysis. Holding times and preservation methods are specified in Table B.1. The holding time begins from the date of collection in the field.

B.4.2 Shipping Requirements

Shipping containers will be secured by using nylon strapping tape and custody seals to ensure that the samples have not been disturbed during transport. The custody seals will be placed on the containers so they cannot be opened without breaking the seal.

FIGURE B.1

SAMPLE CUSTODY SEAL AND SAMPLE LABEL

CUSTODY SEAL

_______________ Date	ENGINEERING-SCIENCE INC. 1700 Broadway, Suite 900
_______________ Signature	Denver, Colorado 80290

SAMPLE IDENTIFICATION LABEL

Ship To: PACE LABORATORY
11 Digital Drive
Novato, California 94949
Attn: Stacy Hock
(415) 883-6100

Sample ID: ____–______–______ Project Name: AFCEE BIOVENTING

ES Project NO.: DE268.____ ____.08 Field Personnel: ____________

Base: ____________ Site: ____________

Date: ____________ Time: ____________

Analyses: ____________

Preservation: ____________

Comments: ____________

TABLE B.2

SAMPLE NUMBERING SYSTEM

The Sample Numbering System includes 3 identifying pieces of information separated by hypens:

[Code for Site] - [Code for Location] - [Depth]

Code for Site - by site provided on Table C.3.

Code for Location - a two letter prefix and letter (indicating which A, B, C only when necessary) will indicate the sample location.

VW - Vent well
MP - Monitoring point
BG - Background well
EB - Exploratory boring or other boring not completed as one of the above

Depth - from the surface where the sample is gathered

Example Sample Numbers

M2 - VW - 12:	Sample from site #2 at Millersworth AFB from a depth of 12 feet from the vent well boring.
M2 - MPC - 28:	Sample from site #2 at Millersworth AFB from a depth of 28 feet from the monitoring point C boring.
M2 - BG - 4:	Sample from site #2 Millersworth AFB from a depth of 4 feet from the background boring.

Soil samples which must be kept cool shall be shipped in insulated containers with either freezer forms or ice. If ice is used, it must be placed in a container so that the water will not fill the cooler as the ice melts. The samples will be delivered as soon as possible after collection to allow the laboratory to meet holding times.

Copies of the signed Chain-of-Custody forms will be delivered with the data packages. The originals will remain on file with the laboratory.

B.4.3 Shipping Addresses

B.4.3.1 Soil Samples

All soil samples will be shipped to the PACE Laboratory

PACE Laboratory
11 Digital Drive
Novato, CA 94949
Attention: Stacy Hock
Phone: (415) 883-6100

B.4.3.2 Soil Gas Samples

Air Toxics LTD
11325 Sunrise Gold Circle, Suite 4
180 Blue Ravine Road, Suite B
Folsom, California 95630
Attention: Alexis Merydith
Phone: (916) 638-985-1000

B.4.4 Sample Receipt

The laboratory will sign the Chain-of-Custody upon receipt, keep the original, and immediately send a signed copy, which describes sample conditions upon receipt, back to the deputy project manager. The condition of the samples and temperature of the cooler will be documented in a signed, dated, and bound log book and on the Chain-of-Custody form with signature and date of person checking samples. If any breakage or discrepancy arises between Chain-of-Custody, sample labels, and requested analysis, the sample custodian will notify the ES deputy project manager immediately. Any breakage, discrepancy, or improper preservation will be noted by the laboratory as an out-of-control form with the corrective action taken. The out-of-control form will be signed and dated by the custodian and any other person responsible for corrective action.

B.5 SAMPLE CUSTODY

All samples will be accompanied by a Chain-of-Custody Record, examples of which are shown in Figures B.2 and B.3. A Chain-of-Custody Record will accompany the sample during shipment to the laboratory and through the laboratory. The Site Manager will fax a copy of each Chain-of-Custody Record to the project administrator, ES Denver (303) 831-8208 for tracking purposes.

FIGURE B.2

CHAIN OF COUSTODY RECORD

Page ___ of ___

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No.
DE268.___ ___.08

AFCEE BIOVENTING PILOT TESTS

Base:

Site:

Sampler(s): (Signature)

Preservative: NONE | HOLD AT 4C | NONE

Analysis Required

Ship To:

PACE LABORATORY
11 Digital Drive
Novato, California 94949
Attn: Stacy Hock
(415) 883-6100

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks:

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: ______________________

Airbill Number: ______________________

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 - Denver, Colorado
(303) 831-8100

CCR80L

FIGURE B.3

CHAIN OF CUSTODY RECORD

Page ___ of ___

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No.
DE268. ___ ___ .08

AFCEE BIOVENTING PILOT TESTS

Base:

Site:

Sampler(s): (Signature)

Preservative: NONE

Analysis Required: TO-3(EPA), (BTEX & TPH)

Ship To:

Air Toxics Ltd.
180 Blue Ravine Rd.
Suite B
Folsom California 95630
Attn: Alexis Merydith

Date	Time	Sample Description	Lab I.D.	No. of Contrs	TO-3(EPA)	(BTEX & TPH)	Sample Type	Matrix	Remarks
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks:

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: ______

Airbill Number: ______

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 - Denver, Colorado
(303) 831-8100

CCRAIR

The information provided on the Chain-of-Custody Record will include:

- The project name and the Air Force Base name;
- The signature of the samplers;
- The sampling station number or sample number;
- Date and time of collection;
- Grab or sample designation;
- A brief description of the type of sample and sampling location;
- Signature of individuals involved in the sample transfer;
- The time and date they receive the sample;
- The type of matrix;
- The preservatives used; and
- The analytical methods required; and
- The number of containers of each sample.

Chain-of-Custody Records initiated in the field shall be placed in a plastic cover and taped to the inside of the shipping containers used for sample transport from the field to the laboratory. This record will be used to document sample custody transfer from the field sampler to the laboratory or to an ES office.

B.5.1 Sample Custody

A sample is under custody if:

- it is in your actual possession; or
- it is in your view, after being in your physical possession; or
- it was in your physical possession and then you locked it up to prevent tampering; or
- it is in a designated and identified secure area.

B.5.2 Transfer of Custody and Shipment

The following procedures will be used in transferring and shipping samples:

- Samples are accompanied by a Chain-of-Custody Record. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the Record. This Record documents transfer of custody of samples from the field sampler to another person, or to the laboratory.
- Samples will be properly packaged for shipment and dispatched to the appropriate laboratory for analysis with a separate signed Chain-of-Custody

Record enclosed in each sample box or cooler. The Chain-of-Custody Records will be numbered 1 of N, 2 of N, ..., where N is equal to the number of coolers shipped each day.

- Whenever samples are split with a facility or government agency, a separate Chain-of-Custody Record will be prepared for those samples and marked to indicate with whom the samples are being split.
- All packages will be accompanied by the Chain-of-Custody Record showing identification of the contents. The original Record will accompany the shipment and copies will be retained by the site manager and in the ES Denver office.

B.5.3 Laboratory Custody Procedures

The analytical laboratory will, as a minimum, record the temperature of the shipping container, check all incoming samples for integrity, and note any observations on the original Chain-of-Custody Record. Each sample will be logged into the laboratory system by assigning it a unique sample number. This number and the field sample identification number will be recorded on the laboratory report. Samples will be stored and analyzed according to specific USEPA methods. After the project is completed, the original Chain-of-Custody Record will be returned to the project manager for permanent storage.

The following procedures will be used by the laboratory sample custodian in maintaining the Chain-of-Custody once the samples have arrived at the laboratory:

- The samples received by the laboratory will be cross-checked to verify that the information on the sample labels matches that on the Chain-of-Custody record included with the shipment;
- If all data and samples are correct, and there has been no tampering with the custody seals, the "received by laboratory" box is signed and dated; and
- The samples will be distributed to the appropriate analysts, with names of individuals who receive samples to be recorded in internal laboratory records.

For data that are input by an analyst and processed using a computer, a copy of the input shall be kept and identified with the project number and other information as needed.

If the data are directly acquired from instrumentation and processed, the analyst will verify that the following are correct:

- Project and sample numbers;
- Calibration constants and response factors;
- Output parameters such as units of measurement; and
- Numerical values used for detection limits if a value is reported as "less than".

B.6 CALIBRATION PROCEDURES AND FREQUENCY

See Test Wells and Equipment, Section 4, of the Protocol Document.

B.7 ANALYTICAL PROCEDURES

Specific chemical parameters for the sampling program were selected based on suspected contaminants released at the Air Force Bases. The analytical program was designed to qualify and quantify the effect of bioventing on a variety of soil types, contamination concentrations, and under different climatic conditions.

B.7.1 Analyses for Organic Compounds and Physical Parameters

All analyses will be performed within the holding times recommended for the specific test procedure and sample matrix. Samples will be collected and shipped in EPA recommended sample containers and preserved as required for specific tests as specified on Table B.1.

B.7.2 Detection Limits

The method detection limits (MDL) for the analyses described above are summarized in Table B.1.

B.8 DATA REDUCTION, VALIDATION AND REPORTING

B.8.1 Field Measurement Data

Field measurements will be made by the site manager or the test engineer. The following standard reporting units will be used during all phases of the project:

- Pressure will be reported to 0.1 standard units on 5", 10", and 15" magnehelics, and reported in inches on larger magnehelics;
- O_2 and CO_2 will be reported to 0.1 percent;
- TVH will be reported in ppmv on the appropriate scale;
- Helium will be reported to 0.1 percent;
- Ambient temperature will be reported to the nearest 0.5 C;
- Soil temperature will be reported to 0.1 C; and
- Soil sampling depths will be reported to the nearest 0.5 foot.

Field data will be validated using three different procedures:

- Routine checks will be made during the processing of data. An example is looking for errors in identification codes.
- Internal consistency of a data set will be evaluated. This step may involve plotting the data and testing for outliers.

- Checks may be made for consistency with parallel data sets, that is, data sets obtained presumably from the same population (for example, from the same region of the aquifer or volume of soil).

The purpose of these validation checks and tests is to identify outliers; that is, an observation that does not conform to the pattern established by other observations. Outliers may be the result of transcription errors or instrumental breakdowns. Outliers may also be manifestations of a greater degree of spatial or temporal variability than expected.

After an outlier has been identified, a decision concerning its fate must be rendered. Obvious mistakes in data will be corrected when possible, and the correct value will be inserted. If the correct value cannot be obtained, the data may be excluded. An attempt will be made to explain the existence of the outlier. If no plausible explanation can be found for the outlier, it may be excluded, but a note to that effect will be included in the report.

B.8.2 Data Analysis and Reporting

During data analysis and report preparation, the accuracy of numbers, calculations, tables, and figures will be reviewed and confirmed. In addition, the technical content of the report will be reviewed by the Project Manager and the report will be edited for syntax, grammar, composition, and printed quality. Data will be reported in AFCEE level 1 format. Data analysis reports will be issued to ES Denver within 30 days of receipt of samples. All data packages will be submitted to the deputy project manager and will include soil and soil gas analysis results. A copy of the Chain-of-Custody Record will be submitted with the analysis results.

B.8.3 Maintenance of Project Documents

See Procedures and Controls of the PMP, Section 5.

B.9 FIELD AND LABORATORY CONTROL CHECKS

B.9.1 Field Quality Control Samples

During each sampling effort, a number of quality control (QC) samples must be collected and submitted for laboratory analysis. The number and frequency of the QC sample collection will be 5 percent (or 1 in 20 samples). A list of the types of QC sample collection will be 5 (or 1 in 20 samples). A list of the types of QC samples that shall be collected along with a brief description of each sample type is outlined in the following sections.

B.9.1.1 Field Duplicates

Five percent of all soil and soil gas samples will be collected in duplicate and submitted for laboratory analysis. Field duplicates will be labeled in such a manner so

that persons performing laboratory analyses are not able to distinguish duplicates from other collected samples.

B.9.2 Laboratory QA/QC Samples

Quality control data are necessary to determine the absence of interferences and contamination of glassware and reagents. All method QA/QC is applied to each sample set at a method-specified frequency; matrix spike and spike duplicate analyses are performed for each matrix type. Duplicate samples and/or matrix spike duplicate samples will be analyzed with each set of samples, one every 20 samples or 5 percent.

B.9.2.1 Analytical Duplicate Analyses

Analytical duplicate samples are aliquots of a single sample that are split on arrival at the laboratory or upon analysis.

B.9.2.2 Matrix Spike/Duplicate Spike Analyses

This technique is used to determine the effect of matrix interference on the results for the GC/MS methods. Aliquots of the same sample are prepared in the laboratory and each aliquot is treated exactly the same throughout the analytical method. Spikes are added at concentrations specified in the method. The percent difference between the values of the duplicates is taken as a measure of the precision of the analytical method.

Selected samples will be spiked to determine accuracy as a percentage recovery of the analyte from the sample matrix. These matrix spikes will be prepared using reagent grade salts, pure compounds, or certified stock solutions whenever possible. Concentrated solutions will be used to minimize differences in the sample matrix resulting from dilution. Samples will be randomly selected and split into identical duplicates, one of which will then be spiked with a known mass of the analyte to be determined. The final concentration after spiking should be within the same range as the samples being analyzed to avoid the need for dilution, attenuation of instrument outputs, or other required alterations in the procedure which might affect the instrument response and determination of accuracy. A matrix spike duplicate sample is prepared in the same manner as the matrix spike sample.

B.10 PREVENTIVE MAINTENANCE

All field equipment, instruments, tools, gauges, and other items requiring preventive maintenance will be serviced in accordance with the manufacturer's specified recommendations. Maintenance records will be documented and traceable to specific equipment.

All laboratory instruments will be maintained in accordance with the standard operating procedures for each instrument. All maintenance will be documented for each analytical instrument.

B.11 CORRECTIVE ACTION

The following procedures have been established to assure that conditions adverse to quality including malfunctions, deficiencies, deviations, and errors are promptly investigated, documented, evaluated, and corrected.

When a significant condition adverse to quality is noted at the project site, laboratory, or subcontractor locations, the cause of the condition will be determined and corrective action taken to preclude repetition. Condition identification, cause, reference documents, and corrective action planned to be taken will be documented and reported to the Project Manager, Quality Assurance Manager, Site Investigation Geologist, and involved subcontractor management, as a minimum. Implementation of corrective action will be verified by documented follow-up action. All project personnel have the responsibility, as part of the normal work duties, to promptly identify, solicit approved correction, and report conditions adverse to quality.

Corrective actions may be initiated as a minimum:

- When predetermined acceptance standards are not attained (objectives for precision, accuracy and completeness);
- When procedures or data compiled are determined to be faulty;
- When equipment or instrumentation is found faulty;
- When samples and test results cannot be traced with certainty;
- When quality assurance requirements have been violated;
- When designated approvals have been circumvented;
- As a result of system and performance audits;
- As a result of a management assessment; or
- As a result of QA audits.

B.12 QUALITY ASSURANCE AUDITS

A quality assurance audit will be performed at least once in each regional office by the Quality Assurance Manager (QAM) or designated alternate. This audit will be performed to evaluate implementation of the QA/QC Plan, and the performance of project personnel, items, activities, and documentation of the measurement systems.

APPENDIX C

FIELD SAMPLING PLAN

C.1 FIELD OPERATIONS

This field sampling plan (FSP) provides guidance for the field procedures to be followed while conducting the activities specified in the Test Plan and Technical Protocol for field Treatability Test for Bioventing (Protocol Document). The following contains procedures for typical venting/bioremediation test activities. Any additional activities specified will be identified in the site-specific test plan.

C.1.1 Site Reconnaissance and Preparation Procedures

Site reconnaissance and preparation procedures include a review of existing site data and an initial base meeting. These are described in the Project Management Plan (PMP) Section 4.2 (page 4-1).

C.1.2 Soil Organic Vapor Survey Procedures

Soil organic vapor (SOV) surveys will be performed to locate the optimum test area. For contamination 20 ft deep or less, an initial soil gas survey will be performed to locate areas of depleted oxygen. For contamination deeper than 20 ft, exploratory borings will be drilled. See the Protocol Document (pages 41, 42, and 43) for procedures for performing the soil gas survey or to identify contaminated soils using exploratory borings.

All soil gas survey and exploratory boring information as well as all other field activity information will be recorded in a permanently bound notebook with sequentially numbered pages.

The date, job number, and initials will be recorded at the top of each page. A sample field log book is included as Figure C.1. Minimum information required for each entry includes:

Time (recorded in the column under the date),

Ambient temperature (³F),

Weather conditions during previous 24 hours,

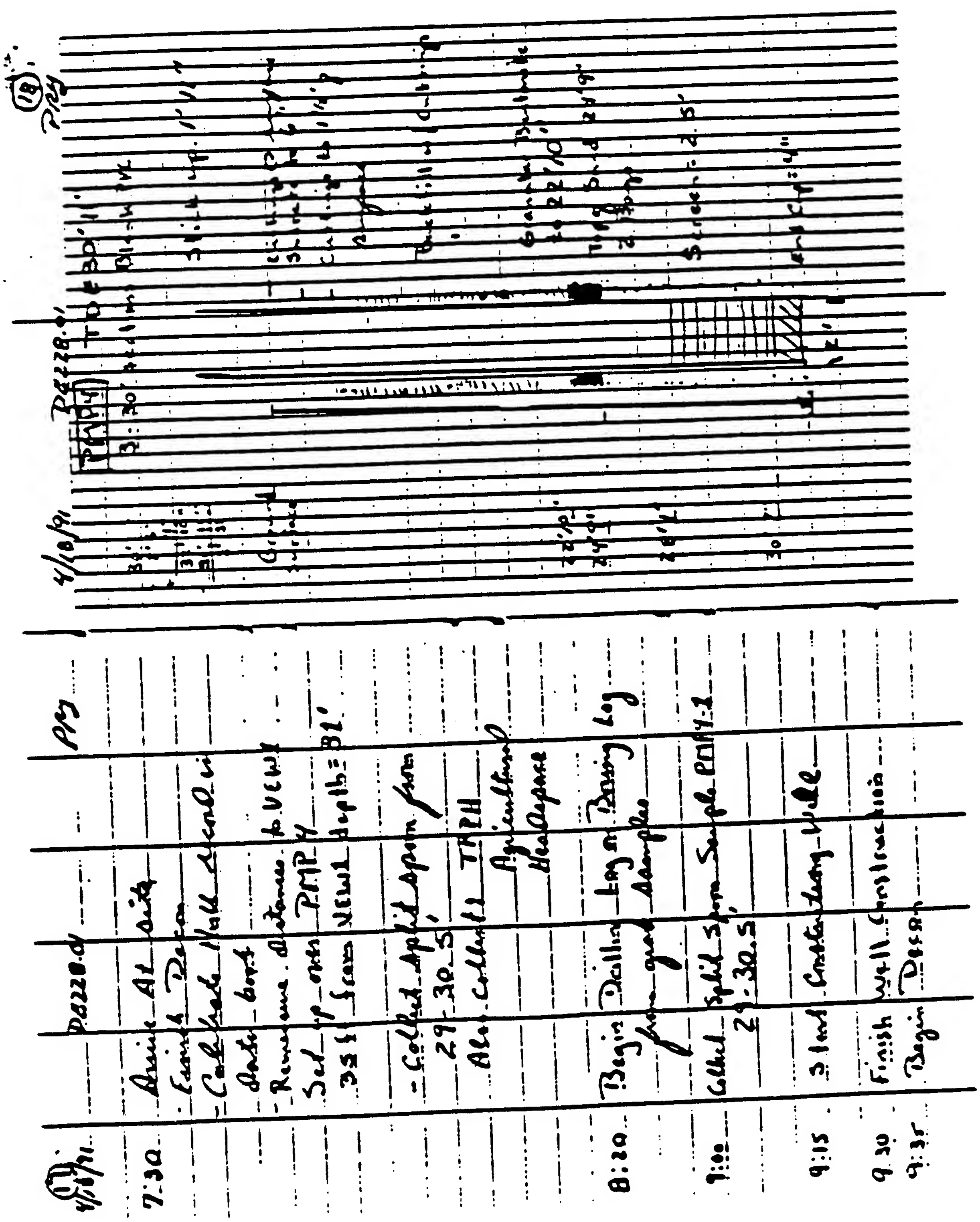
Persons performing the soil gas survey drilling oversight, sampling, or testing,

Drilling and well construction information,

Site identification,

FIGURE C.1

SAMPLE FIELD LOG BOOK



A7-1-23

- Sampling location,
- Sample number,
- Sample media (soil or air),
- Sample type (grab, composite, etc.),
- Sample description,
- Test information including O_2, CO_2 and TVH soil gas concentrations recorded on separate data sheets,
- Chemical analysis to be performed,
- Preservation method,
- Laboratory to which samples were sent and air bill numbers, if applicable,
- Photo numbers and description,
- Equipment decontaminated and procedures utilized,
- Equipment serial numbers,
- Calibrations,
- Field measurements not recorded on other data sheets,
- Description of extended blower test equipment set up,
- Records of pertinent telephone conversations,
- Names, titles, and organization of any visitors entering the site, and
- Comments (suitable for reconstructing incident without memory).

All entries will be made in waterproof ink. Any errors will be corrected by drawing a single line through the mistake, and all corrections will be initialed and dated.

C.1.3 Installation of Vent, Monitoring, and Background Wells

See the Protocol Document Sections 5.2, 5.3, and 5.4 (page 44). Use Figure C.2 for logging each boring.

C.1.4 Well Abandonment and Waste Handling

ES will advise the Air Force on proper well abandonment techniques based on federal, state, and local regulations. Drill cuttings will be handled in accordance with base policy. ES drilling subcontractors may be required to drum drill cuttings for placement in the base hazardous material storage area. Drums will be labelled according to base procedures. Under no circumstances should ES personnel assume responsibility for disposal.

FIGURE C.2

Sheet __ of __

GEOLOGIC BORING LOG

Project Number	________	Client	________	Date	________
Borehole ID	________	Borehole Diameter	________	Elevation	________
Drill Rig	________	Contractor	________	Datum	________
Temp (°F):	________	Weather	________	Geologist	________
		Drilling Medium	________		

Depth (ft.)	Profile	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks TIP = Reading (ppm)
1								
5								
10								
15								
20								
25								
30								
35								
40								

sl - slight	v - very	fn - fine	SPLIT SPOON SAMPLE
tr - trace	lt - light	m - medium	GRAB SAMPLE
sm - some	dk - dark	crs - coarse	▲ WATER TABLE DRILLED
& - and	bf - buff	[illegible] - Borehole	
@ - at	brn - brown	SAA - Same As Above	
w - with	blk - black	D - Drawer ________	

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C.2 ENVIRONMENTAL SAMPLING PROCEDURES

C.2.1 Soil Sampling Procedures

For the number, types of samples and corresponding containers see Table D-1. Initial and final soil samples will be collected from the following locations on each site:

The most contaminated depth of the Vent Well (VW) which is the central injection or extraction well and

Two monitoring points (MPs) including one sample from the most contaminated depths of the <u>closest</u> and the <u>second</u> <u>closest</u> <u>MPs</u> to the VW.

C.2.1.1 Soil Sampling for BTEX and TRPH

Soil samples will generally be obtained using a truck-mounted hollow-stem auger rig and split-spoon sampler containing brass tubes. The split-spoon sampler will be driven by a 140-pound drop hammer having a 30-inch drop. The sampler will be driven for its full length or until 6 inches, or less, of penetration is achieved after 50 blows.

If required by regulatory agencies, soil samples will be handled according to individual base sampling and analysis plans (SAP). If there is no established base SAP, immediately upon removal from the split-spoon sampler, the ends of one of the brass liners will be trimmed with a decontaminated stainless steel knife or spatula and sealed with oil-free aluminum foil or covered with a Teflon® fabric. The foil or fabric will be held in place on the ends of each tube by plastic caps sealed with tape. Soil in this liner will be extruded in the laboratory immediately prior to analysis for VOCs.

C.2.1.2 Soil Sampling for Physical Parameters

Soil in the remaining liners or soil from drill cuttings or hand augering will be placed into appropriate sample containers (see Table C.1), or used for field measurement surveys and visual descriptions.

C.2.2 Soil Gas Sampling Procedures

The purpose of soil gas sampling and analysis is to determine the initial levels of benzene, toluene, ethylbenzene, and xylenes (BTEX) and total volatile hydrocarbons (TVH) in the soil gas to predict potential air emissions and to determine the reduction in BTEX and TVH during the one year test and to detect migration of these vapors from the source area.

Initial and final soil gas samples will be collected from the following locations on each site:

Central injection or extraction well, VW and

Two MPs including one sample from the <u>closest</u> <u>MP</u> where a soil sample has been taken and another gas sample from the <u>furthest</u> <u>MP</u> from the VW.

TABLE C.1

Sample Analysis Type, Number, and Container

SAMPLE MEDIUM	LABORATORY ANALYSIS TYPE	PARAMETER	APPROXIMATE NUMBER a/ SOIL SAMPLES BY SITE		SAMPLE CONTAINER			PRESERVATIVE
			INITIAL #	FINAL #	NUMBER	SIZE	TYPE	
SOIL	INORGANIC	pH ALKALINITY IRON, TOTAL SOIL MOISTURE CONTENT	3	0	1	4 OUNCE	GLASS	NONE
	ORGANIC	BTEX b/ TRPH c/	3	3	1	4 OUNCE	2" DIA. BRASS TUBE	HOLD AT 4 C
	SEQUOIA ANALYTICAL INORGANIC	TOTAL KJELDAHL NITROGEN TOTAL PHOSPHATE	3	0	1	16 OUNCE	GLASS	NONE
	PHYSICAL	SOIL CLASSIFICATION						
AIR	ORGANIC	BTEX AND TVH d/	3	3	1	1 LITER	SUMMA (a) CANISTER	NONE DO NOT CHILL

a/ On samples requiring MS/MSD (normally 1 MS/MSD per 20 project samples), triple sample volume; e.g. 3 brass tubes for BTEX and TRPH.
b/ BTEX – benzene, toluene, ethylbenzene, and xylenes.
c/ TRPH – total recoverable petroleum hydrocarbons.
d/ TVH – total volatile hydrocarbons.

TABD1/OES/BIOVENTING/6.10.92

Prior to collecting soil gas samples, the vent well and the monitoring points must be purged with a 1 CFM pump. approximately three times the well or probe volume should be purged. To determine adequate purging time, soil gas concentrations should be monitored until the concentrations stabilize or until the oxygen concentration reaches a minimum level. The $CO_2/0_2$ analyzer will be connected to the outlet of the sampling pump with a "tee" connection as shown in Figure 5.1 of the protocol document. The pump can be connected to the vent well using a combination of fittings as shown in Figure C.3. Soil gas samples should be taken immediately upon completion of purging.

A sample will be collected in a 1-liter evacuated stainless steel (SUMMA®) canister provided by the analytical laboratory. A simple checklist and diagram for operating these canisters is provided (Figure C.4). Because the canisters are evacuated, when they are opened, the sample is collected almost instantaneously. According to the laboratory, one does not need to record pressure and temperature because the samples are brought to standard pressure and temperature in the lab. One sample in twenty (5%) should be a field duplicate.

In silt and clay soils the soil gas sample will first be collected in a new 2-liter Tedlar® bag using a vacuum chamber (egg) connected to the vapor well. The Tedlar® bag will then be connected to the evacuated cylinder using a 6-inch section of clean Tygon® tubing. The gas is then transferred from the Tedlar® bag by first opening the Tedlar® bag valve and then opening the valve on the evacuated cylinder. The sample will transfer rapidly. Once the transfer is complete, the valve on the cylinder should be immediately closed and sealed with a piece of tape to prevent reopening.

In sandy soils, the evacuated cylinder can be connected directly to a purged vapor monitoring point and the cylinder valve opened to draw a soil gas sample from the well. Check to insure the gas sample is properly labelled using the nomenclature described in Section 4.2.3 of the Protocol Document.

C.3 SAMPLE HANDLING

C.3.1 Soil Samples

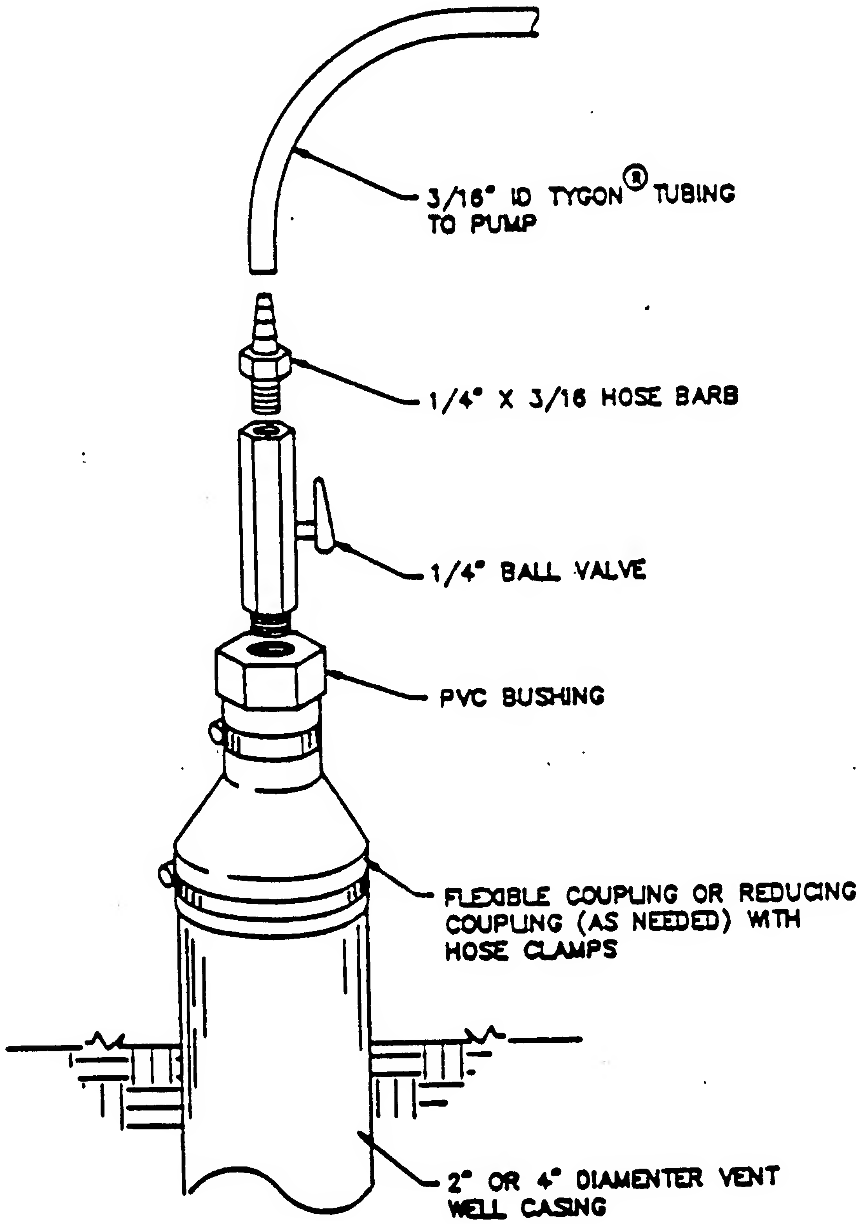
Sample handling is addressed in the QAPP in Appendix B. Site managers are responsible for contacting the PACE Laboratory to alert them to the number of samples that will be sent for analyses.

C.3.2 Soil Gas Samples

Samples and chain of custody form should be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples should not be sent on ice as this will cause condensation of hydrocarbons and degrade sample integrity.

FIGURE C.3

TYPICAL WELL HEAD CONFIGURATION FOR SOIL GAS SAMPLING



NOT TO SCALE

FIGURE C-4

INSTRUCTIONS FOR TAKING SAMPLES USING SUMMA® CANISTERS

Required Equipment:

Evacuated SUMMA® canisters
a 2-7 micron filter
a 1/2" open end wrench
a 9/16" open end wrench
a hose barb adapter to adapt the threaded fitting on the canister to 3/16" Tygon® tubing.

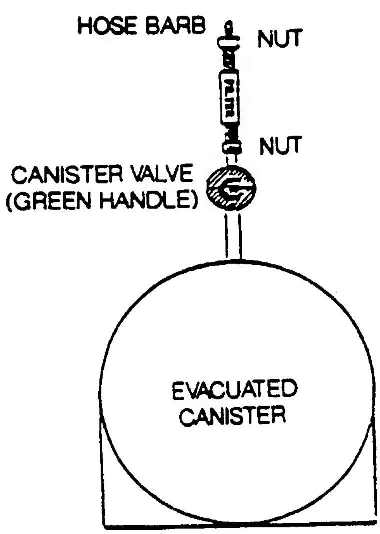
Assembly of the sampling hardware:

1. Remove the brass cap from the canister.
2. Connect the filter to the canister. Tighten the filter to the canister using the 9/16" wrench.
3. Connect the hose barb to the filter.
4. Connect the well head or the Tedlar® bag to the hose barb using 3/16" Tygon® tubing (using as short a connector as possible).

The assembly is now complete...sampling will commence when the valve on the canister (green handle) is opened.

The Final Step

When the sample interval is complete, close the valve (green handle) on the canister and remove the filter. It is not necessary to over-tighten the valve upon closing. Replace the brass cap. Fill out the sampling tracking tag. The canister may now be submitted to Analytical Technologies, Inc. for analysis.



C.4 FIELD MEASUREMENTS

Typical field parameters that may be measured and the equipment that will be used for the measurements are described in Table C.2. Details of the equipment calibration, maintenance, and decontamination are also described in Table C.3.

C.5 FIELD QA/QC PROGRAM

Field measurement parameters, control checks, control limits, and corrective actions are identified in Table C.3.

C.6 BIOVENTING PILOT TEST

See the Protocol Document (pages 46-60).

C.7 FIELD SYSTEMS OPERATION AND MONITORING

C.7.1 Pressure/Vacuum Monitoring

Dwyer Instruments Magnehelic\ gauges with a range of 0 to 200 inches of water-column will be used to measure pressure/vacuum at the VMPs. The pressure/vacuum measurements will be taken manually by connecting the Magnehelic\ gauge to each VMP. The gauges should be read to 0.1 of the smallest standard unit.

Operating time for each test will be recorded from the time the blower is turned on. Pressure/vacuum at each VMP, and at each measurement location on the vacuum extraction (VE) unit, will be recorded at 1, 5, 10, 15, 20, 30, 40, 50, and 60 minutes, and every 60 minutes thereafter. After the initial 12 hours of operation, vacuum measurements will be recorded every 4 to 8 hours.

C.7.2 Temperature Monitoring

Ambient temperature will be measured using a mercury thermometer during the use of direct reading instruments to account for data variability possibly due to temperature.

Soil temperature will be measured using type J thermocouples placed at a minimum of two MPs per site.

C.7.3 Helium Monitoring

Helium concentrations in extracted soil gas will be measured using a Marks Helium Detector 9821. The instrument is factory calibrated but should be checked with a 1 percent helium standard to insure it remains within ±5 percent of factory calibration.

C.7.4 Oxygen and Carbon Dioxide Monitoring

Both oxygen and carbon dioxide will be monitored with a Gastechtor\ Model 3252OX gas analyzer. This instrument includes an infrared detector for carbon dioxide and an electrochemical cell for oxygen analysis, and is capable of measuring both compounds to within an accuracy of 0.1 percent. The instrument requires daily

TABLE C.2

FIELD MEASUREMENTS

PARAMETER	EQUIPMENT	CALIBRATION	SOURCE OF CALIBRATION STANDARDS	EQUIPMENT MAINTENANCE	EQUIPMENT DECONTAMINATION
Pressure/ Vacuum	Dwyer Instruments Magnehelic® Gauge	Calibrated By Manufacturer	Not Applicable	Replace in case of malfunction	Not Applicable
Temperature	Mercury Thermometer	Calibrated by Manufacturer	Not Applicable	Replace in case of malfunction	Rinse thermometer with distilled water after each use and blot or shake to remove excess water.
Soil Temperature	Type J Thermocouple	Check with ambient temperature and ice	Mercury thermometer	Follow manufacturers procedures	Rinse probe with distilled water. Remove excess water.
Helium	Marks Helium	Calibrated by Manufacture	Not Applicable	Follow manufacturers procedures	Rinse probe with distilled water. Remove excess water.
O_2/CO_2	GasTech® Analyzer	Two-point calibration	Commercially available gas mixes	Follow manufacturers procedures	Rinse probe with distilled water. Remove excess water.
Total Volatile Hydrocarbons	GasTech® Analyzer	Two-point calibration	Commercially available gas mixes	Follow manufacturers procedures	Rinse probe with distilled water. Remove excess water.

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Table C.3

CONTROL PARAMETERS, CONTROL LIMITS, AND CORRECTIVE ACTIONS

Measurement Parameter	Control Checks	Control Limits	Corrective Action[a]
Pressure/ Vacuum	Check measurement	± 1" water	Replace gauge
Temperature	Check measurement	± 1 degree centigrade thermometer	Replace or correct temperature readings
Soil Temperature	Check measurement	± 1 degree centigrade	Replace thermocouple or return reader to manufacturer
Helium	Calibration Std.	± 5% of value	If calibration exceeds ±5%, return to manufacturer Check battery Clean Filter
O_2/CO_2	Calibrate Stds.	± 5% of value	Recalibrate Check battery Clean Filter
Total Volatile Hydrocarbons	Calibrate Daily Check Battery	± 100ppm	Recalibrate Check battery Clean Filter

a/ Required if control limits not achieved

calibration with a 5 percent carbon dioxide gas mixed in laboratory-grade nitrogen. The same calibration gas can also be used to provide a zero for oxygen.

C.7.5 Total Volatile Hydrocarbons

Hydrocarbon concentrations in extracted soil gas will be measured using a GasTech\ Trace-Techtor Hydrocarbon Analyzer, model 72-8418E-O2.

APPENDIX D
TEST PLAN AND TECHNICAL PROTOCOL FOR A FIELD TREATABILITY TEST FOR BIOVENTING

Revision 2

TEST PLAN AND TECHNICAL PROTOCOL

FOR

A FIELD TREATABILITY TEST FOR BIOVENTING

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May 1992

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TEST PLAN AND TECHNICAL PROTOCOL FOR A FIELD TREATABILITY TEST FOR BIOVENTING

1.0 TEST OBJECTIVES

This test plan and technical protocol describes the methods for conducting a field treatability test for the bioventing technology. The purpose of these field test methods is to measure the soil gas permeability and microbial activity at a contaminated site and to evaluate the potential application of the bioventing technology to remediate the contaminated site. The specific test objectives are stated below.

1.1 Conduct Air Permeability and In Situ Respiration Tests

At every site, the air permeability of the soil and the air vent (well) radius of influence will be determined. This will require air to be withdrawn or injected for approximately 8 hours at vent wells located in contaminated soils. Pressure changes will be monitored in an array of monitoring points. Immediately following this test, an in situ respiration test will be conducted. Air will be injected into selected monitoring points to aerate the soils. The in situ oxygen utilization and carbon dioxide production rates will be measured.

1.2 Conduct Bioventing Test

Using the data from the soil air permeability and in situ respiration tests, an air injection/withdrawal rate will be determined for use in the bioventing test. A blower will be selected, installed, and operated for 6 to 12 months, and periodic measurements of the soil gas composition will be made, to evaluate the long-term effectiveness of bioventing.

1.3 Use of Existing Wells and Monitoring Points

The U.S. Air Force has already installed monitoring points or other wells at many sites that will be suitable for use in this study. In keeping with the objective of developing a cost-effective program for site remediation, every effort will be made to use existing wells and minimize drilling costs.

2.0 INTRODUCTION TO BIOVENTING AND FIELD TREATABILITY TESTS

Bioventing is the process of aerating subsurface soils to stimulate in situ biological activity and promote bioremediation. Although it is related to the process of soil venting (aka soil vacuum extraction, soil gas extraction, and in situ soil stripping), their primary objectives are different. Soil venting is designed and operated to maximize the volatilization of low-molecular-weight compounds, with some biodegradation occurring. In contrast, bioventing is designed to maximize biodegradation of aerobically biodegradable compounds, regardless of their molecular weight, with some volatilization occurring. The major difference between these technologies is that the objective of soil venting is volatilization, and the objective of bioventing is biodegradation. Although both technologies involve venting of air through the subsurface, the differences in objectives result in different design and operation of the remedial systems.

2.1 Bioventing Background

Petroleum distillate hydrocarbons such as JP-4 jet fuel are generally biodegradable if the naturally occurring microorganisms that acclimate to the fuels as a carbon source are provided an adequate supply of oxygen and basic nutrients (Atlas, 1986). Natural biodegradation does occur, and at many sites microorganisms may eventually mineralize most of the fuel contamination. However, the process is dependent on natural oxygen diffusion rates (Ostendorf and Kambell, 1989). As a result, natural biodegradation is frequently too slow to prevent the spread of contamination and sites may require remediation to protect sensitive aquifers. Acceleration or enhancement of the natural biodegradation process may prove to be the most cost-effective remediation for hydrocarbon-contaminated sites.

Understanding the distribution of contaminants is important to any in situ remediation process. Much of the hydrocarbon residue at a fuel-contaminated site is found in the unsaturated zone soils, in the capillary fringe, and immediately below the water table. Seasonal water table fluctuations typically spread residues in the area immediately above and below the water table. Any successful bioremediation effort must treat these areas. Bioventing provides oxygen to unsaturated zone soils and can be extended below the water table when integrated with a dewatering system.

2.1.1 Conventional Enhanced Biodegradation

The practice of enhanced biodegradation for treating soluble fuel components in groundwater has increased over the past two decades (Lee et al., 1988), with less emphasis given to enhancing biodegradation in the unsaturated zone. Currently, conventional enhanced bioreclamation processes use water to carry oxygen or an alternative electron acceptor to the contaminated zone. This is common whether the contamination is present in the groundwater or in the unsaturated zone.

A recent field experiment at a jet fuel-contaminated site used infiltration galleries and spray irrigation to introduce oxygen (as hydrogen peroxide), nitrogen, and phosphorus to unsaturated, sandy soils. The experiment was unsuccessful because the rapid decomposition of hydrogen peroxide resulted in poor oxygen distribution (Hinchee et al., 1989).

Other attempts have been made using pure oxygen or hydrogen peroxide as oxygen sources, and recently nitrate has been added as an alternative to oxygen. Although results indicate better hydrogen peroxide stability than achieved by Hinchee et al. (1989), it was concluded that most of the hydrogen peroxide decomposed rapidly (Huling et al., 1990). Some degradation of aromatic hydrocarbons appears to have occurred; however, no change in total hydrocarbon contamination levels was detected in the soils (Ward, 1988).

In most cases where water is used as the oxygen carrier, the solubility of oxygen is the limiting factor for biodegradation. If pure oxygen is used and 40 mg/l of dissolved oxygen is achieved, approximately 80,000 lb of water must be delivered to the formation to degrade 1 lb of hydrocarbon. If 500 mg/l of hydrogen peroxide is successfully delivered, then approximately 13,000 lb of water must be used to degrade the same amount of hydrocarbon. As a result, even if hydrogen peroxide can be successfully used, substantial volumes of water must be pumped through the contaminated formation to deliver sufficient oxygen.

2.1.2 Bioventing

A system engineered to increase the microbial biodegradation of fuel hydrocarbons in the unsaturated zone using forced air as the oxygen source may be a cost-effective alternative to conventional systems. This process provides oxygen to indigenous soil microorganisms promoting aerobic metabolism of fuel hydrocarbons in unsaturated soils. Depending on airflow rates, some volatile compounds may be simultaneously stripped from contaminated soils.

When air is used as an oxygen source, 13 lb of air must be delivered to provide the minimum oxygen required to degrade 1 lb of hydrocarbon, compared to the more than 13,000 lb of water with 500 mg/l of hydrogen peroxide that must be delivered by conventional water phase-enhanced bioreclamation processes. An additional advantage of using a gas phase process is that gases have greater diffusivity than liquids. At many sites, geological heterogeneities cause fluid that is pumped through the formation to be channeled into the more permeable pathways (e.g., in an alluvial soil with interbedded sand and clay, all of the fluid flow initially takes place in the sand). As a result, oxygen must be delivered to the less permeable clay lenses through diffusion. In a gaseous system (as found in unsaturated soils), this diffusion can be expected to take place at rates several orders of magnitude greater than rates in a liquid system (as is found in saturated soils). Although it is not realistic to expect diffusion to aid significantly in water-based bioreclamation, diffusion of oxygen in a gas phase system may be a significant mechanism for oxygen delivery to less permeable zones.

To the authors' knowledge, the first documented evidence of unsaturated zone biodegradation resulting from forced aeration was reported by the Texas Research Institute, Inc., in a study for the American Petroleum Institute. A large-scale model experiment was conducted to test the effectiveness of a surfactant treatment to enhance the recovery of spilled gasoline. The experiment accounted for only 8 gal of the 65 gal originally spilled and raised questions about the fate of the gasoline. Subsequently, a column study was conducted to determine a diffusion coefficient for soil venting. This column study evolved into a biodegradation study in which it was concluded that as much as 38% of the fuel hydrocarbon was biologically mineralized. Researchers concluded that venting would not only remove gasoline by physical means, but also could enhance microbial activity and promote biodegradation of the gasoline (Texas Research Institute, 1980; 1984).

To the authors' knowledge, the first actual field-scale bioventing experiments were conducted by van Eyk for Shell Oil. In 1982 at van Eyk's direction, Delft Geotechnics in The Netherlands initiated a series of experiments to investigate the effectiveness of bioventing for treating hydrocarbon-contaminated soils. These studies are reported in a series of papers (Anonymous, 1986; Staatsuitgeverij, 1986; van Eyk and Vreeken, 1988, 1989a and 1989b).

Wilson and Ward (1986) suggested that using air as a carrier for oxygen could be 1,000 times more efficient than using water, especially in deep, hard-to-flood unsaturated zones. They made the connection between soil venting and biodegradation by observing that "soil venting uses the same principle to remove volatile components of the hydrocarbon." In a general overview of the soil venting process, Bennedsen et al. (1987) concluded that soil venting provides large quantities of oxygen to the unsaturated zone, possibly stimulating aerobic degradation. They suggested that water and nutrients would also be required for significant degradation and encouraged additional investigation into this area.

Biodegradation enhanced by soil venting has been observed at several field sites. Investigators claim that at a soil venting site for remediation of gasoline-contaminated soil significant biodegradation occurred (measured by a temperature rise) when air was supplied. Investigators pumped pulses of air through a pile of excavated soil and observed a consistent rise in temperature, which they attributed to biodegradation. They claimed that the pile was cleaned up during the summer primarily by biodegradation (Conner, 1988). However, they did not control for natural volatilization from the aboveground pile, and not enough data were published to critically review their biodegradation claim.

Researchers at Traverse City, Michigan, observed a decrease in the toluene concentration in unsaturated zone soil gas, which they measured as an indicator of fuel contamination in the unsaturated zone. They assumed that advection had not occurred and attributed the toluene loss to biodegradation. The investigators concluded that because toluene concentrations decayed near the oxygenated ground surface, soil venting is an attractive remediation alternative for biodegrading light volatile hydrocarbon spills (Ostendorf and Kambell, 1989).

The U.S. Air Force initiated its research and development (R&D) program in bioventing in 1988 with a study at Hill Air Force Base (AFB) in Utah. During this study it became apparent that bioventing had great potential for remediating JP-4 fuel-contaminated soils. It was also apparent that additional research would be needed before the technology could be routinely applied in the field. The work was initially supported by the U.S. Air Force Civil Engineering Support Agency (AFCESA), previously known as the Air Force Engineering and Services Center. Subsequently, they were joined in R&D support of the technology by the U.S. Air Force Center for Environmental Excellence (AFCEE) and later by Hill and Eielson AFBs. Following the Hill AFB study, a more controlled bioventing study was completed at Tyndall AFB in Florida.

The Air Force currently supports a number of field programs to further test and demonstrate the technology. After completion of the initial site testing at Hill AFB, a low-intensity bioreclamation research program at another site was initiated in late 1989. At Eielson AFB near Fairbanks, Alaska, a field demonstration of bioventing in a subarctic environment was initiated in the summer of 1991. This study includes a soil heating experiment to attempt to increase biodegradation rates.

The U.S. EPA Risk Reduction Engineering Laboratory (RREL) has become interested in the Air Force's program, and has jointly funded and technically supported the work at both Hill and Eielson AFBs. Additionally, the AFCESA is supporting a well-documented bioventing demonstration at a cold weather site with field work scheduled to begin in the summer of 1992.

2.1.3 Applications

The use of an air-based oxygen supply for enhancing biodegradation relies on airflow through hydrocarbon-contaminated soils at rates and configurations that will (1) ensure adequate oxygenation for aerobic biodegradation, and (2) minimize or eliminate the production of a hydrocarbon-contaminated off-gas. The addition of nutrients and moisture may be desirable to increase biodegradation rates; however, field research to date does not indicate the need for these additions (Dupont et al., 1991; Miller et al., 1991). If found necessary, nutrient and moisture addition could take any of a variety of configurations. Dewatering may at times be necessary, depending on the distribution of contaminants relative to the water table. A key feature of bioventing is the use of narrowly screened soil gas monitoring points to sample gas in short vertical sections of the soil. These points are required to monitor local oxygen concentrations, because oxygen levels in the vent well are not representative of local conditions.

A conventional soil venting system could be installed to draw air from a vent well in the area of greatest contamination. This configuration would allow straightforward monitoring of the off-gases. However, its disadvantage is that hydrocarbon off-gas concentration would probably be maximized, and could require permitting and treatment. Furthermore, all of the capillary fringe contamination may not be treated.

Figure 2-1 is a schematic representation of a bioventing system that involves air injection only. Although this is the lowest cost configuration, careful consideration must be given to the fate of injected air. The objective is for most, if not all, of the hydrocarbons to be degraded, and for CO_2 to be emitted at some distance from the injection point. If a building or subsurface structure were to exist within the radius of influence of the well, hydrocarbon vapors might be forced into that structure. Thus, protection of subsurface structures may be required.

Figure 2-2 is an illustration of a configuration in which air is injected (the injection may also be by passive well) into the contaminated zone and withdrawn from clean soils. This configuration allows the more volatile hydrocarbons to degrade prior to being withdrawn, thereby eliminating contaminated off-gases. This configuration typically does not require air emission permitting (site-specific exceptions may apply).

Figure 2-3 illustrates a configuration that may alleviate the threat to subsurface structures while achieving the same basic effect as air injection alone. In this configuration, soil gas is extracted near the structure of concern and reinjected at a safe distance. If necessary, makeup air can be added before injection.

Figure 2-4 illustrates a conventional soil venting configuration at sites where hydrocarbon emissions to the atmosphere are not a problem. This may be the preferred configuration. Dewatering, nutrient, and moisture additions are also illustrated. Dewatering will allow more effective treatment of deeper soils. The optimal configuration for any given site will, of course, depend on site-specific conditions and remedial objectives.

The significant features of this technology include the following:

- Optimizing airflow to reduce volatilization while maintaining aerobic conditions for biodegradation

- Monitoring local soil gas conditions to assure aerobic conditions, not just monitoring vent gas composition

- Adding moisture and nutrients as required to increase biodegradation rates although, as stated earlier, it appears from field studies that this may not be necessary at many if not most sites

- Manipulating the water table (dewatering) as required for air/contaminant contact.

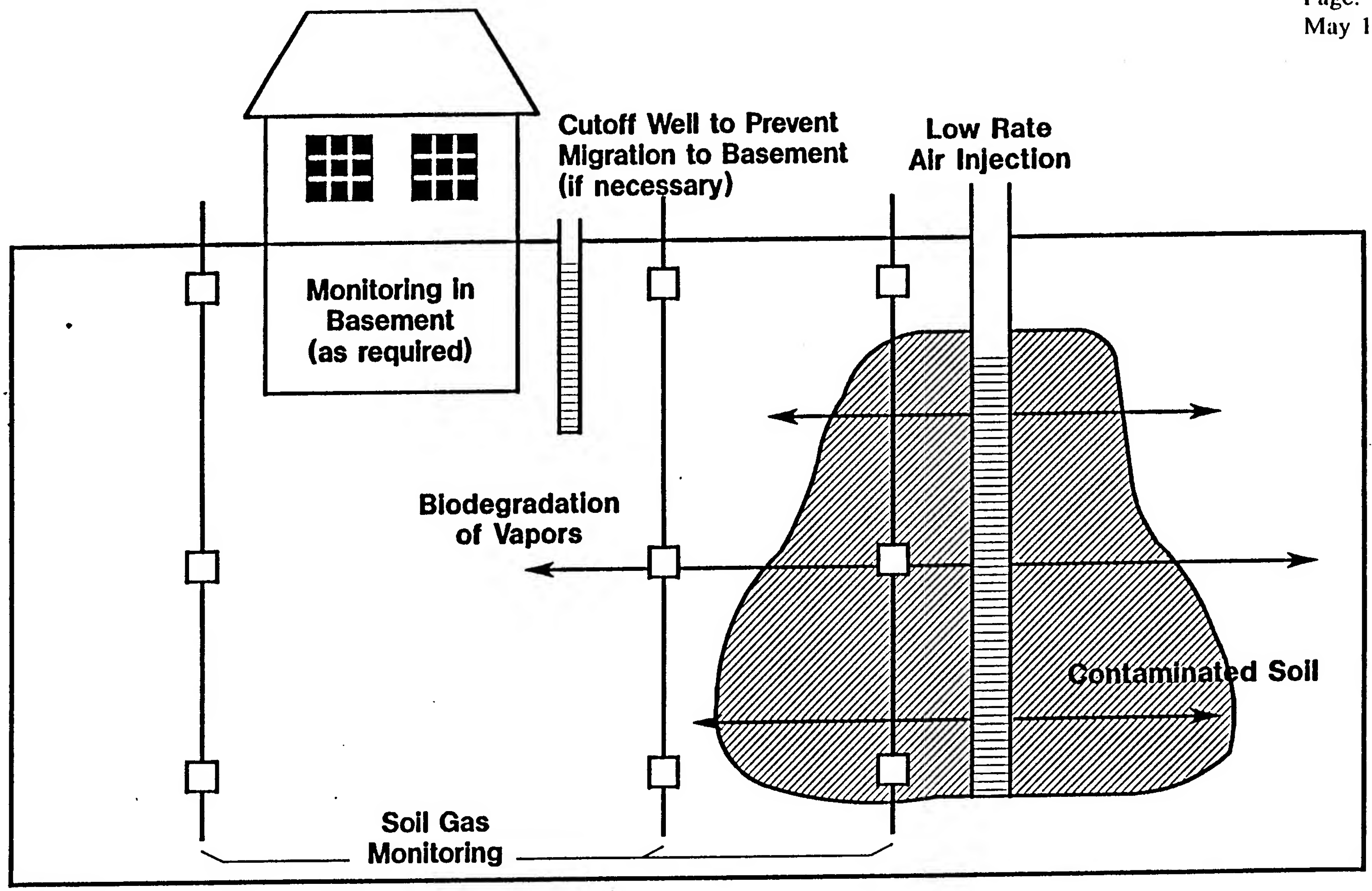

Figure 2-1. Conceptual Layout of Bioventing Process with Air Injection Only.

KA/Hinchee/37-2

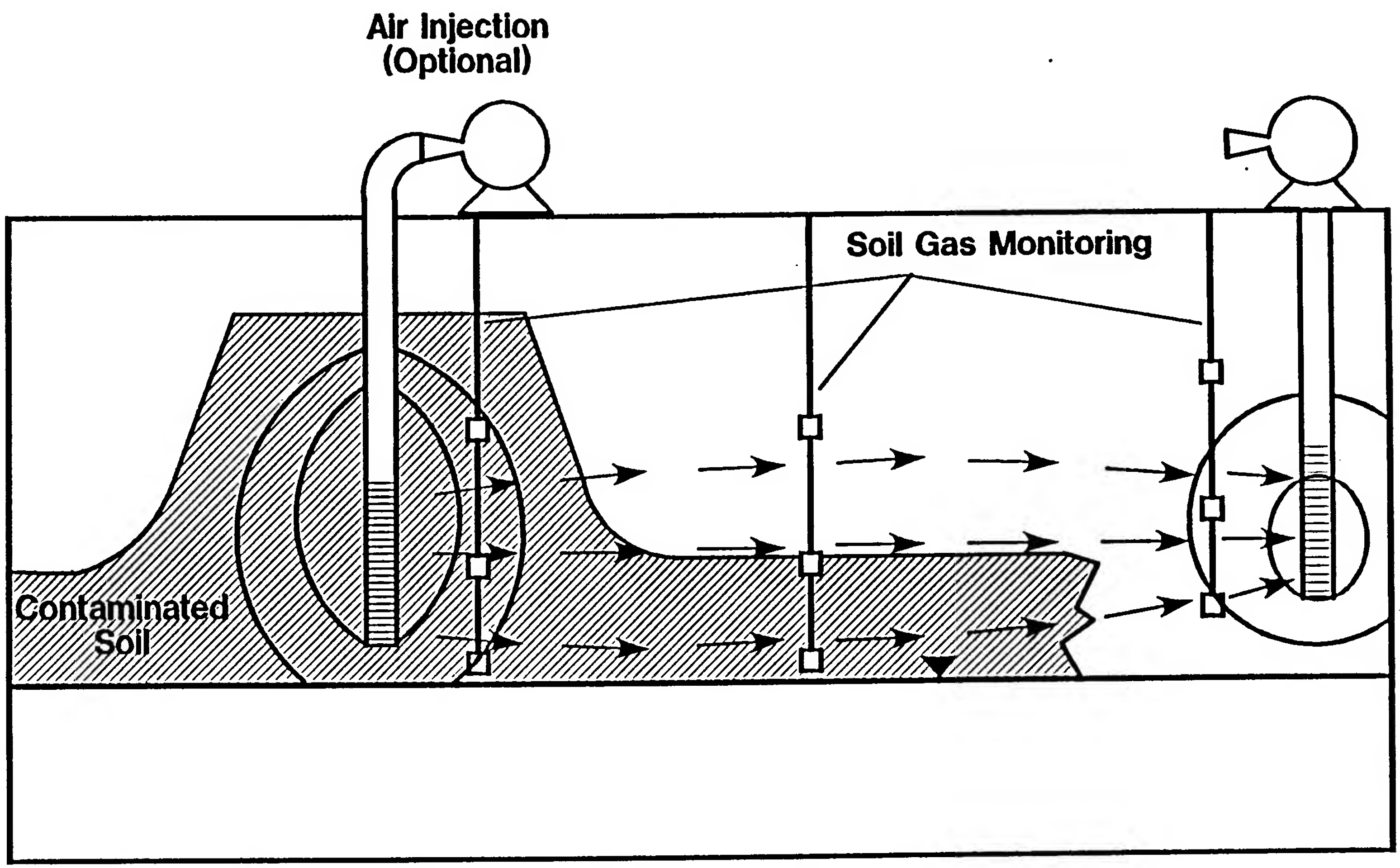

Figure 2-2. Conceptual Layout of Bioventing Process
with Air Withdrawn from Clean Soil.

KA/Org/5-05

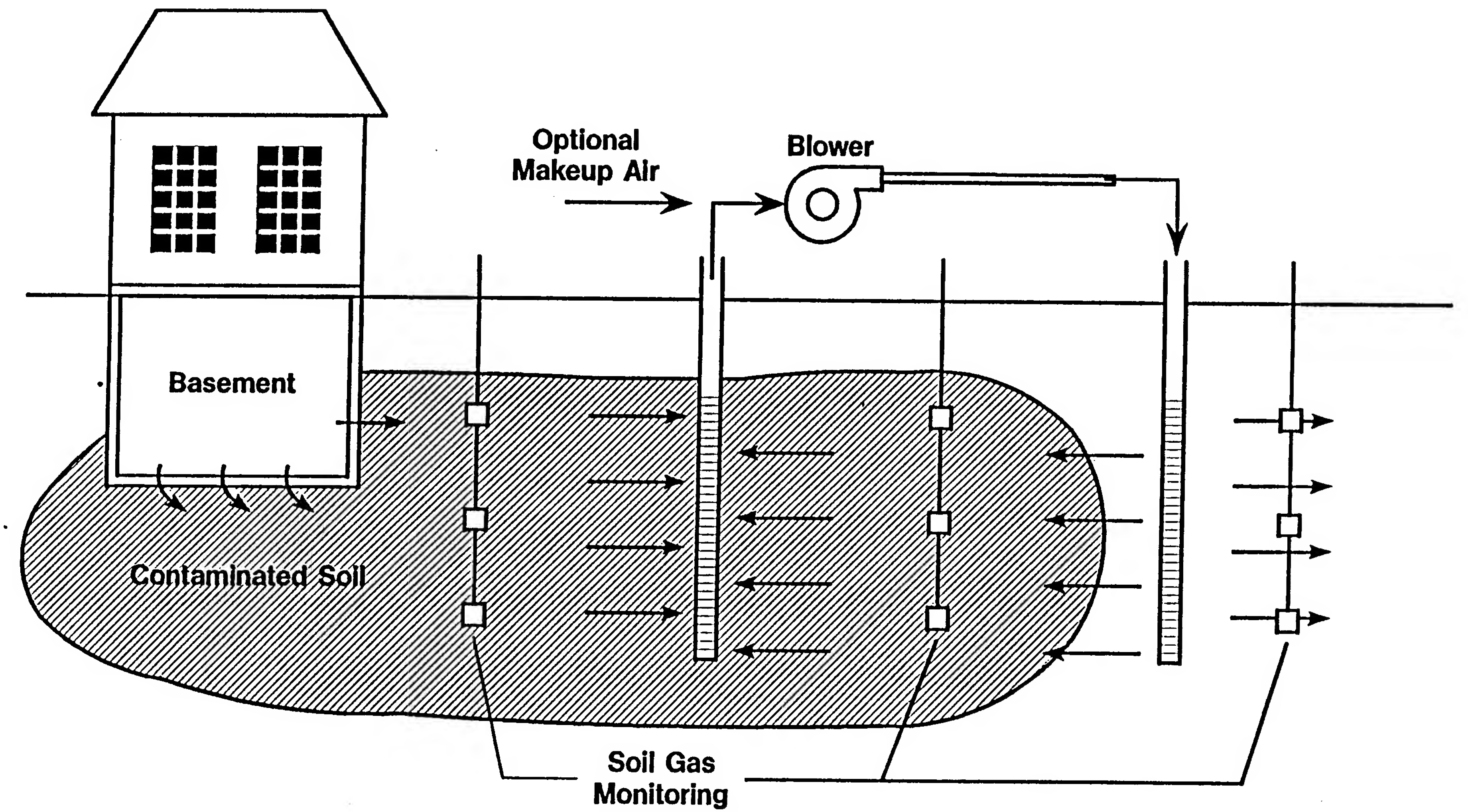

Figure 2-3. Conceptual Layout of Bioventing Process with Soil Gas Reinjection.

KA/Hinchee/37-03b

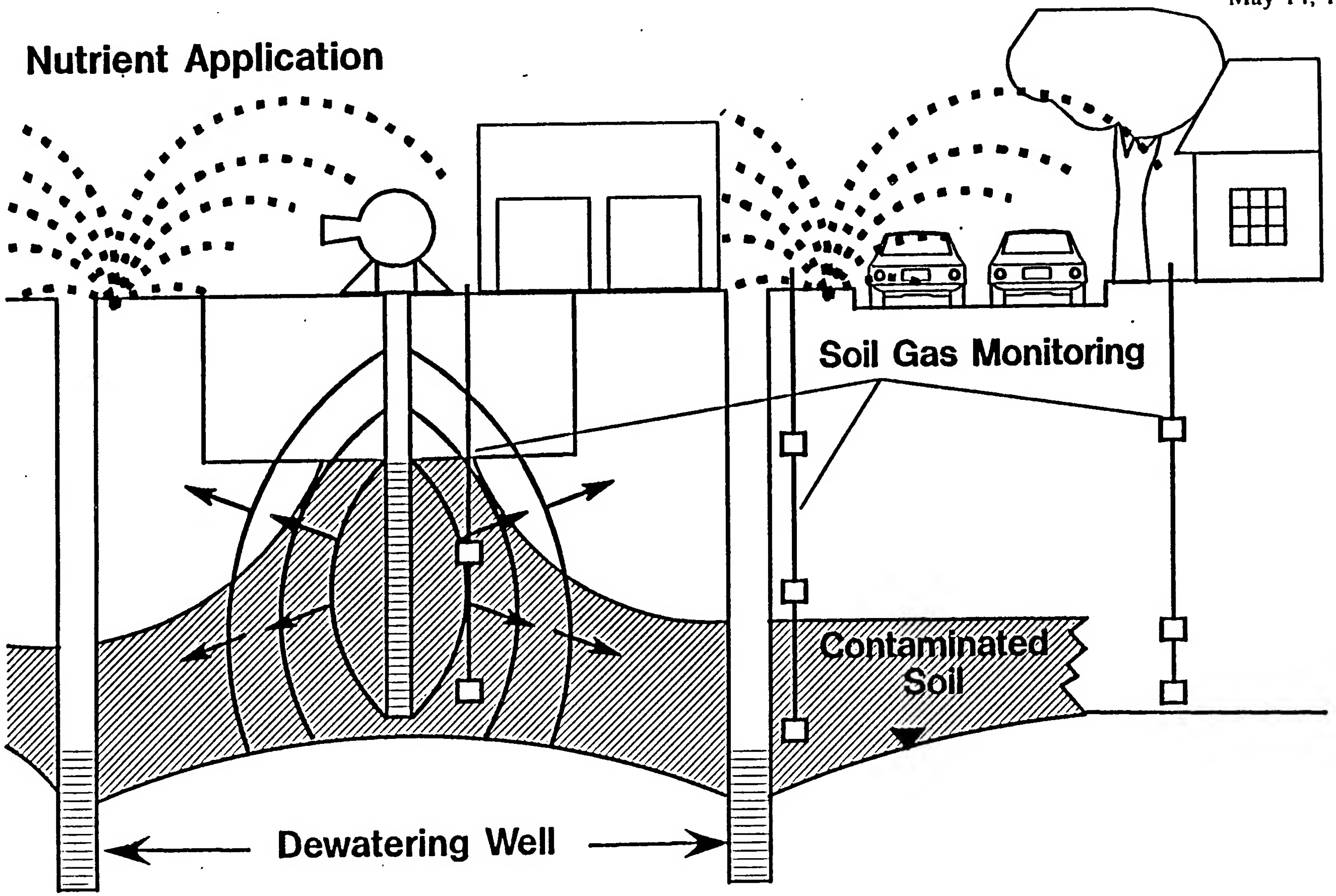

Figure 2-4. Conceptual Layout of Bioventing Process with Air Injection into Contaminated Soil, Coupled with Dewatering and Nutrient Application.

KA/Hinchee/37h07

2.1.4 Hill AFB Site

A spill of approximately 25,000 gal of JP-4 jet fuel occurred when an automatic overflow device failed at Hill AFB in Ogden, Utah. Contamination was limited to the upper 65 ft of a delta outwash of the Weber River. This surficial formation extends from the surface to a depth of approximately 65 ft and is composed of mixed sand and gravel with occasional clay stringers. Depth to regional groundwater is approximately 600 ft; however, water may occasionally be found in discontinuous perched zones. Soil moisture averaged less than 6% in the contaminated soils.

The collected soil samples had JP-4 fuel concentrations up to 20,000 mg/kg, with an average concentration of approximately 400 mg/kg (Oak Ridge National Laboratory, 1989). Contaminants were unevenly distributed to depths of 65 ft. Vent wells were drilled to approximately 65 ft below the ground surface and were screened from 10 to 60 ft below the surface. A background vent was installed in an uncontaminated location in the same geological formation approximately 700 ft north of the site.

Venting was initiated in December 1988 by air extraction at a rate of ~25 cfm. The off-gas was treated by catalytic incineration, and it was initially necessary to dilute the highly concentrated gas to remain below explosive limits and within the incinerator's hydrocarbon operating limits. The venting rate was gradually increased to ~1,500 cfm as hydrocarbon concentration levels dropped. During the period between December 1988 and November 1990, more than 3.5×10^8 ft^3 of soil gas were extracted from the site. In November 1989, ventilation rates were reduced to between ~300 and 600 cfm to provide aeration for bioremediation while reducing off-gas generation. This change allowed removal of the catalytic incinerator, saving ~$6,000 per month.

During extraction, oxygen and hydrocarbon concentrations in the off-gas were measured. To quantify the extent of biodegradation at the site, the oxygen was converted to an equivalent basis. This was based on the stoichiometric oxygen requirement for hexane mineralization. JP-4 hydrocarbon concentrations were determined based on direct readings of a total hydrocarbon analyzer calibrated to hexane. Based on these calculations, the mass of the JP-4 fuel as carbon removed was ~115,000 lb volatilized and 93,000 lb biodegraded. Figures 2-5 and 2-6 illustrate these results.

Hinchee and Arthur (1991) conducted bench-scale studies using soils from this site and found that, in the laboratory, both moisture and nutrients became limiting after aerobic conditions were achieved. This led to the addition of first moisture and then nutrients in the field. The results of these field additions are shown in Figure 2-5. Moisture addition clearly stimulated biodegradation; nutrient addition did not.

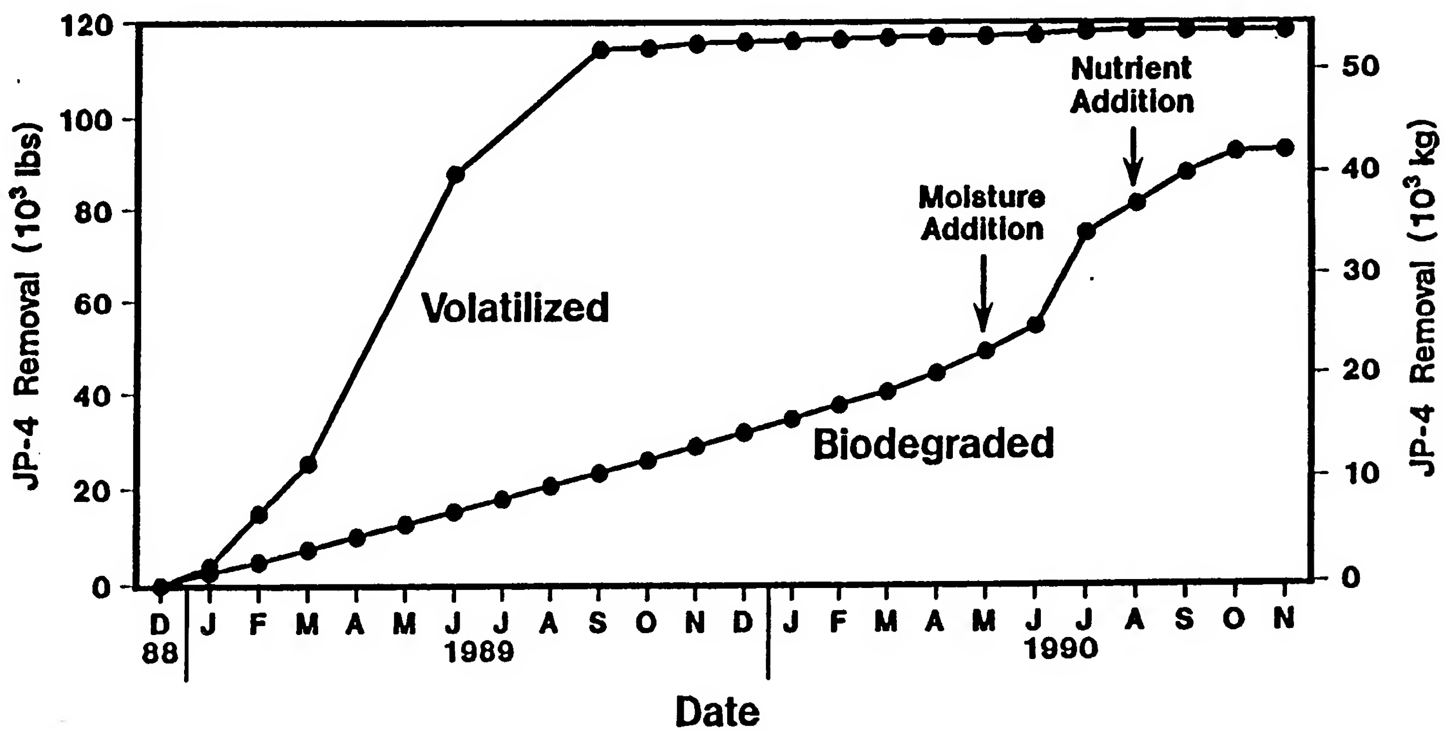

Figure 2-5. Cumulative Hydrocarbon Removal from the Hill AFB Building 914 Soil Venting Site.

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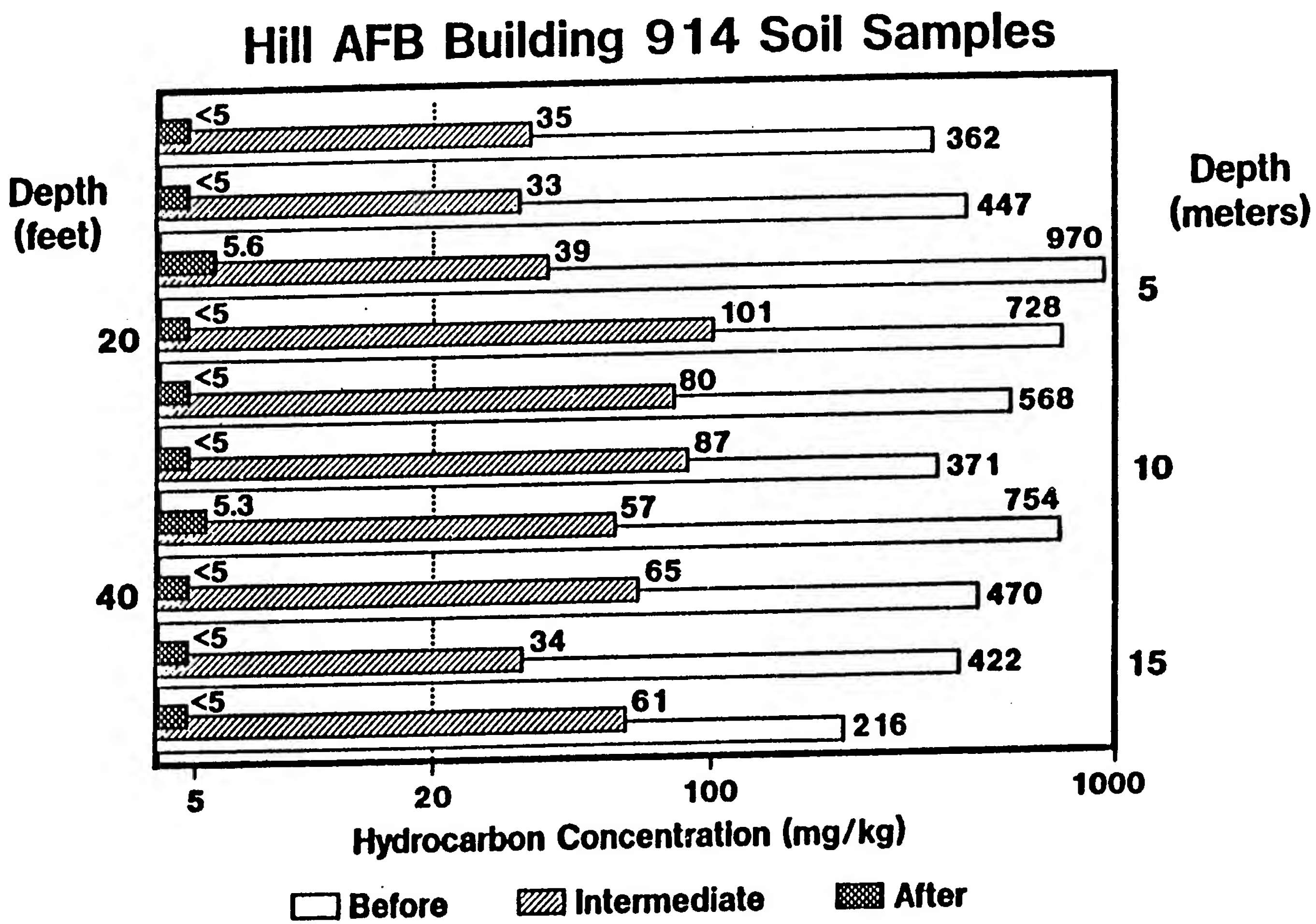

Figure 2-6. Results of Soil Analysis at Hill AFB Before and After Venting. (Each bar represents the average of 14 or more samples.)

The failure to observe an effect of nutrient addition could be explained by a number of factors, including:

- The nutrients failed to move in the soils; this is a problem particularly for ammonia and phosphorus (see Aggarwal et al., 1991).
- Remediation of the site was entering its final phase, and the nutrient addition may have been too late to result in an observed change.
- Nutrients simply may have not been limiting.

2.1.5 Tyndall AFB Site

As a follow-up to the Hill AFB research, a more controlled study was designed at Tyndall AFB. The experimental area in this study was located at a site where past JP-4 fuel storage had resulted in contaminated soils. The nature and volume of fuel spilled or leaked were unknown. The site soils are a fine- to medium-grained quartz sand. The depth to groundwater is 2 to 4 ft.

Four test cells were constructed to allow control of gas flow, water flow, and nutrient addition. Test cells V1 and V2 were installed in the hydrocarbon-contaminated zone; the other two were installed in uncontaminated soils. Initial site characterization indicated the mean soil hydrocarbon levels were 5,100 and 7,700 mg of hexane-equivalent/kg in treatment plots V1 and V2, respectively. The contaminated area was dewatered, and hydraulic control was maintained to keep the depth to water at ~5.25 ft. This exposed more of the contaminated soil to aeration. During normal operation, airflow rates were maintained at approximately one air-filled void volume per day.

Biodegradation and volatilization rates were much higher at the Tyndall AFB site than those observed at Hill AFB; these higher rates were likely due to higher average levels of contamination, warmer temperatures, and the presence of moisture. After 200 days of aeration, an average hydrocarbon reduction of ~2,900 mg/kg was observed. This represents a reduction in total hydrocarbons of approximately 40%.

The study was terminated because the process monitoring objectives had been met; biodegradation was still vigorous. Although the total petroleum hydrocarbons had been reduced by only 40%, the low-molecular-weight aromatics — benzene, toluene, ethylbenzene, and xylenes (BTEX) — were reduced by more than 90% (see Figure 2-7). It appears that the bioventing process more rapidly removes the BTEX compounds than the other JP-4 fuel constituents.

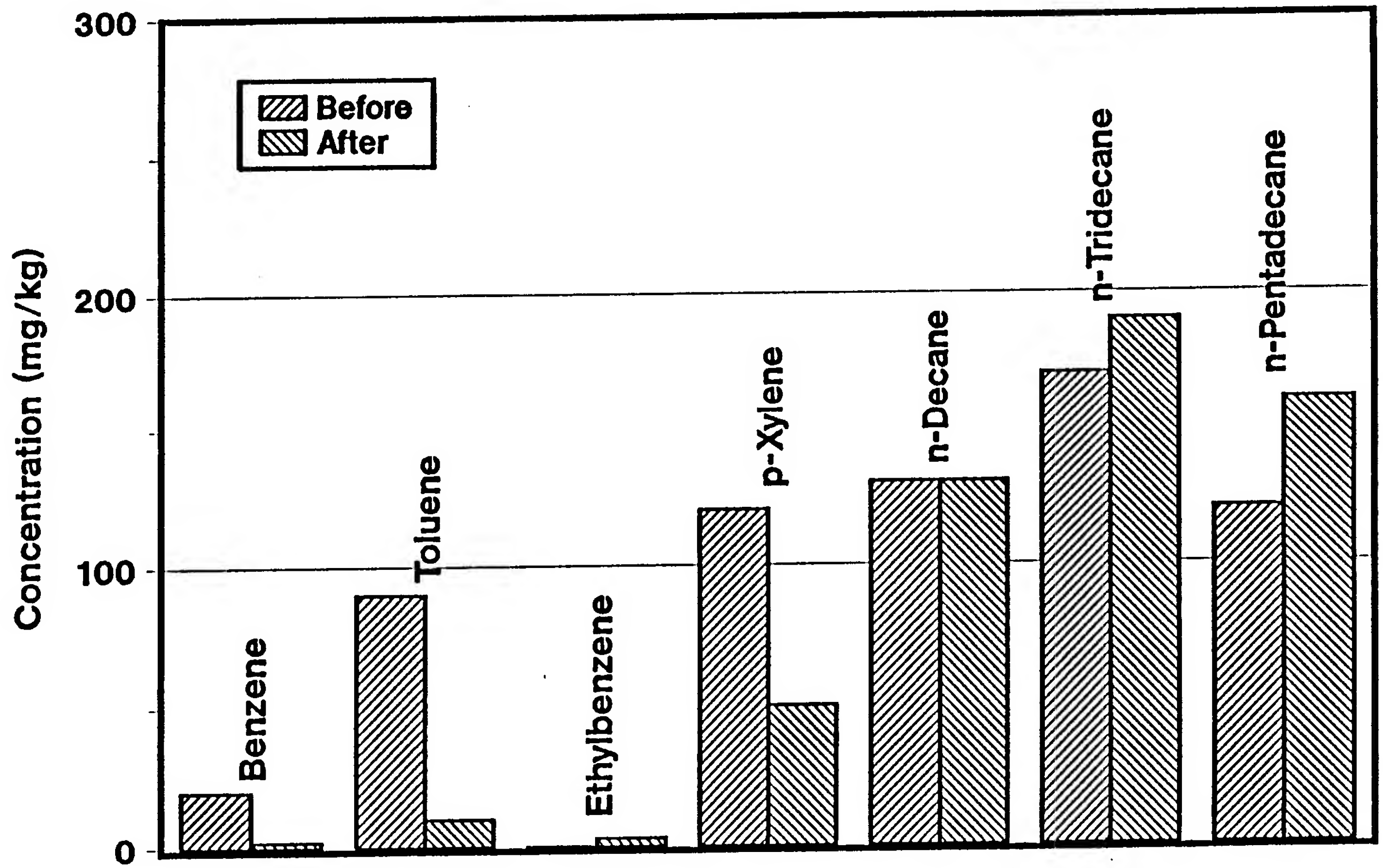

Figure 2-7. Results of Soil Analysis from Plot V2 at Tyndall AFB Before and After Venting. Each bar represents the average of 21 or more soil samples.

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Another important observation of this study is the effect of temperature on the biodegradation rate. Miller (1990) found that the van Hoff-Arrhenius equation provided an excellent model of temperature effects. In the Tyndall AFB study, soil temperature varied by only ~7°C, yet biodegradation rates were approximately twice as high at 25°C than at 18°C.

In the Tyndall AFB study, the effects of moisture and nutrients were observed in a field test. Two side-by-side plots received identical treatment, except that one (V2) received both moisture and nutrients from the outset of the study while the other plot (V1) received neither for 8 weeks, then moisture only for 14 weeks, followed by both moisture and nutrients for 7 weeks. As illustrated in Figure 2-8, no significant effect of moisture or nutrients was observed. The lack of moisture effect contrasts with the Hill AFB findings, but is most likely the result of contrasting climatic and hydrogeologic conditions. Hill AFB is located on a high-elevation desert with a very deep water table. Tyndall AFB is located in a moist subtropical environment, and at the site studied, the water table was maintained at a depth of approximately 5.25 ft.

The nutrient findings support field observations at Hill AFB that the addition of nutrients does not stimulate biodegradation. Based on acetylene reduction studies, Miller (1990) speculates that adequate nitrogen was present due to nitrogen fixation. Both the Hill and Tyndall AFB sites were contaminated for several years before the bioventing studies, and both sites were anaerobic. It is possible that nitrogen fixation, which is maximized under these conditions, provided the required nutrients. In any case, these findings show that nutrient addition is not always required.

In the Tyndall study, a careful evaluation of the relationship between air flow rates and biodegradation and volatilization was made. It was found that extracting air at the optimal rate for biodegradation resulted in 90% removal by biodegradation and 10% removal by volatilization. It was also found that passing the 10% volatilized through clean soil resulted in complete biodegradation.

2.2 Soil Gas Permeability and Radius of Influence

An estimate of the soil's permeability to fluid flow (k) and the radius of influence (R_I) of venting wells are both important elements of a full-scale bioventing design. On-site testing provides the most accurate estimate of the soil gas permeability, k. On-site testing can also be used to determine the radius of influence that can be achieved for a given well configuration and its flow rate and air pressure. These data are used to design full-scale systems, specifically to space venting wells, to size blower equipment, and to ensure that the entire site receives a supply of oxygen-rich air to sustain in situ biodegradation.

Soil gas permeability, or intrinsic permeability, can be defined as a soil's capacity for fluid flow, and varies according to grain size, soil uniformity, porosity, and moisture content. The value of k is a physical property of the soil; k does not change with different extraction/injection rates or different pressure levels.

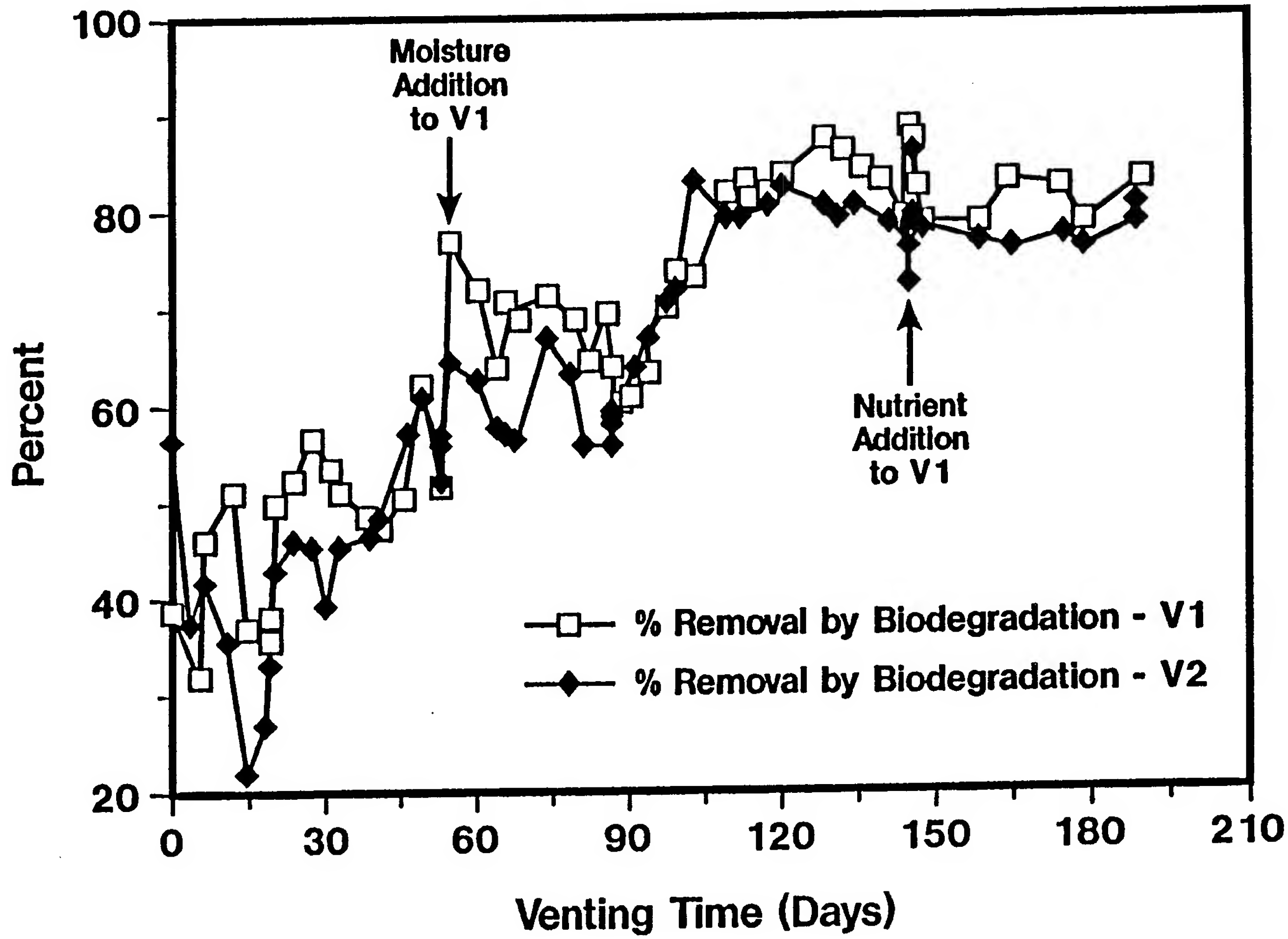

Figure 2-8. Cumulative Percent Hydrocarbon Removal at Tyndall AFB for Sites V1 and V2.

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Soil gas permeability is generally expressed in the units cm^2 or darcy (1 darcy = 1×10^{-8} cm^2). Like hydraulic conductivity, soil gas permeability may vary by more than an order of magnitude on the same site due to soil variability. Table 2-1 illustrates the range of typical k values to be expected with different soil types.

TABLE 2-1. Soil Gas Permeability Values

Soil Type	k in Darcy
Coarse Sand	100-1000
Medium Sand	1-100
Fine Sand	0.1-1.0
Silts/Clays	<0.1

Source: Johnson et al. (1990)

The radius of influence is defined as the maximum distance from the air extraction or injection well where measurable vacuum or pressure (soil gas movement) occurs. R_I is a function of soil properties, but is also dependent on the configuration of the venting well and extraction or injection flow rates, and is altered by soil stratification. On sites with shallow contamination, the radius of influence can also be increased by impermeable surface barriers such as asphalt or concrete. These paved surfaces may or may not act as vapor barriers. Without a tight seal to the native soil surface, the pavement will not significantly impact soil gas flow.

Several field methods have been developed for determining soil gas permeability (see review by Sellers and Fan, 1991). The most favored field test method is probably the modified field drawdown method developed by Paul Johnson and associates at the Shell Development Company. This method involves the injection or extraction of air at a constant rate from a single venting well while measuring the pressure/vacuum changes over time at several monitoring points in the soil away from the venting well. A detailed description of the method, including equations to compute k, is presented in the Appendix.

2.3 In Situ Respiration Testing

As part of the Air Force's bioventing R&D program, a test was identified to provide rapid field measurement of in situ biodegradation rates so that a full-scale bioventing system can be designed. This section describes such a test as developed by Hinchee et al. (1991b). This respiration test has been used at numerous sites throughout the United States.

The in situ respiration test described in this protocol (Sections 4.0 and 5.0) is essentially the same with minor modifications.

The in situ respiration test consists of placing narrowly screened soil gas monitoring points into the unsaturated zone fuel-contaminated and uncontaminated soils and venting these soils with air containing an inert tracer gas for a given period of time. The apparatus for the respiration test is illustrated in Figure 2-9. In a typical experiment, two monitoring point locations — the test location and a background control location — were used. A cluster of three to four probes were usually placed in the contaminated soil of the test location. A 1 to 3% concentration of inert gas was added to the air, which was injected for about 24 hours. The air provided oxygen to the soil, while inert gas measurements provided data on the diffusion of O_2 from the ground surface and the surrounding soil and assured that the soil gas sampling system did not leak. The background control location was placed in an uncontaminated site with air injection to monitor natural background respiration.

Measurements of CO_2 and O_2 concentrations in the soil gas were taken before any air and inert gas injection. After air and inert gas injection were turned off, CO_2 and O_2 and inert gas concentrations were monitored over time. Before a reading was taken, the probe was purged for a few minutes until the CO_2 and O_2 readings were constant. Initial readings were taken every 2 hours and then progressively over 4- to 8-hour intervals. The experiment was usually terminated when the O_2 concentration of the soil gas was ~5%.

The monitoring points in contaminated soil at each site showed a significant decline in O_2 over a 40- to 80-hour monitoring period. Figure 2-10 illustrates the average results from four sites, along with the corresponding O_2 utilization rates in terms of percent of O_2 consumed per hour. In general, little or no O_2 utilization was measured in the uncontaminated background well. Inorganic uptake of O_2 was assumed to be negligible, as seen by the low available iron present in the soil. Aerating the soil for 24 hours was assumed to be sufficient to oxidize any ferrous ions. Table 2-2 provides a summary of in situ respiration rates and reported bioventing data.

The biodegradation rates measured by the in situ respiration test appear to be representative of those for a full-scale bioventing system. Miller (1990) conducted a 9-month bioventing pilot project at Tyndall AFB at the same time Hinchee et al. (1991b) were conducting their in situ respiration test. The O_2 utilization rates (Miller, 1990) measured from nearby active treatment areas were virtually identical to those measured in the in situ respiration test.

CO_2 production proved to be a less useful measure of biodegradation than O_2 disappearance. The biodegradation rate in milligrams of hexane-equivalent/kilograms of soil per day based on CO_2 appearance is usually less than can be accounted for by the O_2 disappearance. The Tyndall AFB site was an exception. That site had low-alkalinity soils and low-pH quartz sands, and CO_2 production actually resulted in a slightly higher estimate of biodegradation (Miller, 1990).

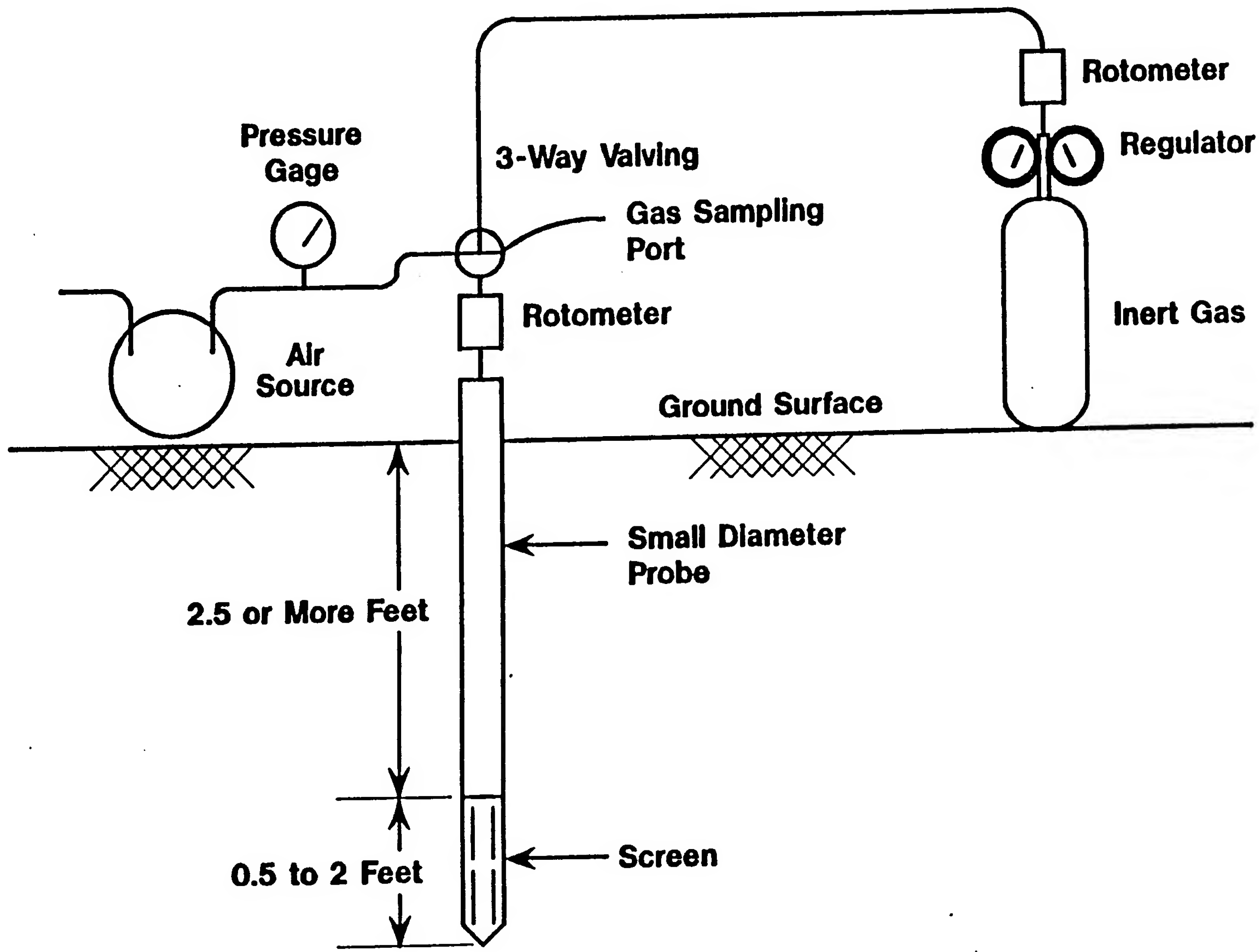

Figure 2-9. Gas Injection/Soil Gas Sampling Monitoring Point Used by Hinchee et al. (1991) in Their In Situ Respiration Studies.

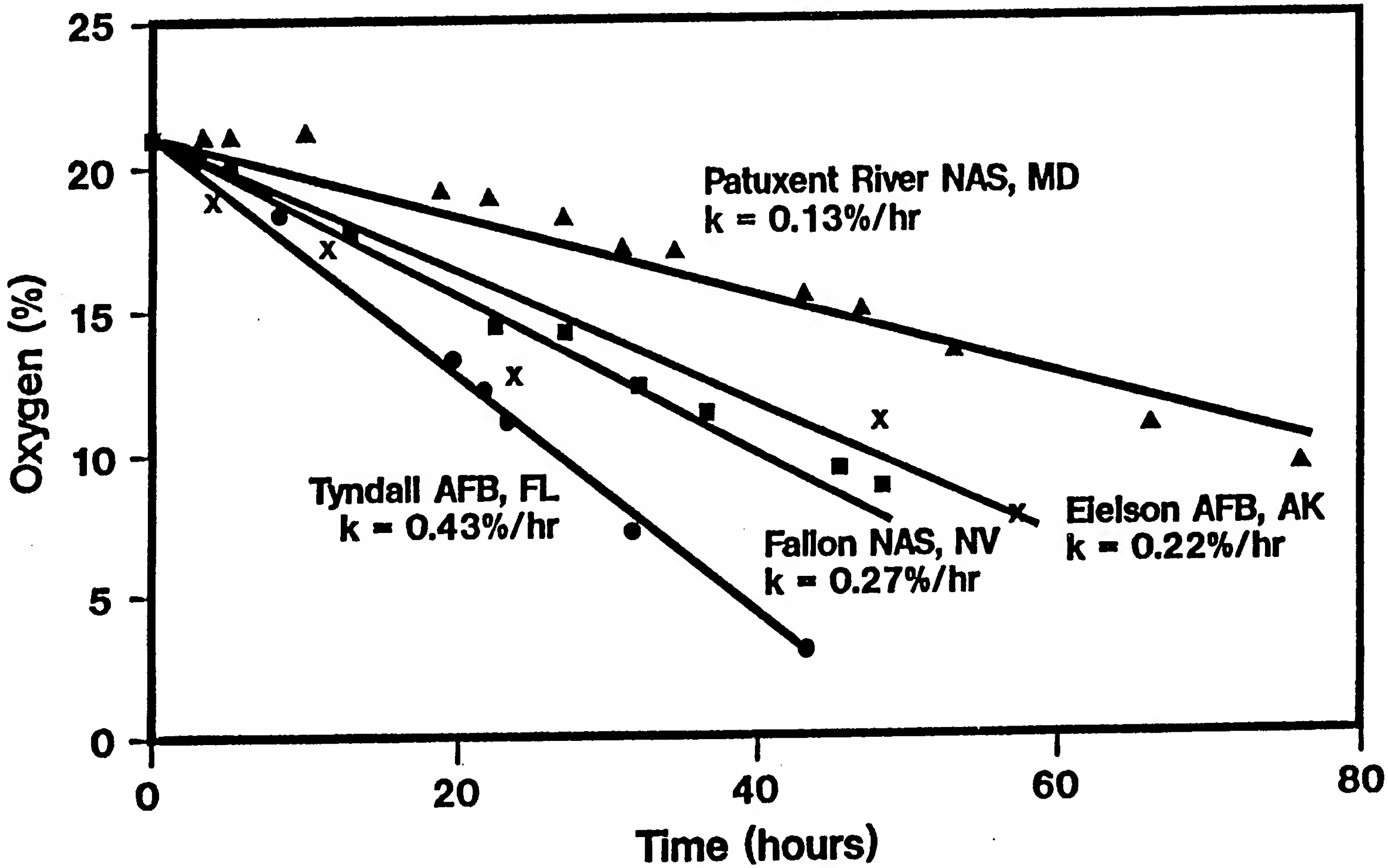

Figure 2-10. Average Oxygen Utilization Rates Measured at Four Test Sites.

TABLE 2-2. Summary of Reported In Situ Respiration and Bioventing Rate Data.

Site	Scale of Application	Contaminant	In Situ Respiration Rates (% O_2/hr)	Estimated Biodegradation Rates	Reference
Hill AFB, Utah	Full-scale, 2 years	JP-4 jet fuel	up to 0.52	Up to 10 mg/(kg day)[a,b]	Hinchee et al., 1991a
Tyndall AFB, Florida	Field pilot, 1 year and in situ respiration test	JP-4 jet fuel	0.1 - 1.0	2-20 mg/(kg day)	Miller, 1990 and Hinchee et al., 1991b
The Netherlands	Undefined	Undefined	0.1 - 0.26	2-5 mg/(kg day)[b]	Urlings et al., 1990
The Netherlands	Field pilot, 1 year	Diesel	0.42	8 mg/(kg day)	van Eyk and Vreeken, 1989b
Undefined	Full scale	Gasoline and diesel	—	50 kg/(well day)[c]	Ely and Heffner, 1988
Undefined	Full scale	Diesel	—	100 kg/(well day)[c]	Ely and Heffner, 1988
Undefined	Full scale	Fuel oil	—	60 kg/(well day)[c]	Ely and Heffner, 1988
Patuxent River NAS, Maryland	In situ respiration test	JP-5 jet fuel	0.16	3 mg/(kg day)	Hinchee et al., 1991b
Fallon NAS, Nevada	In situ respiration test	JP-5 jet fuel	0.26	5 mg/(kg day)	Hinchee et al., 1991b
Eielson AFB, Alaska	In situ respiration test	JP-4 jet fuel	0.05 - 0.5	1-10 mg/(kg day)	Hinchee et al., 1991b
Kenai, Alaska	In situ respiration test	Crude Petroleum	1.1	21 mg/(kg day)	Hinchee and Ong, 1991
Tinker AFB, Oklahoma	In situ respiration test	JP-4 and mixed fuels	0.14 - 0.94	2.7 - 18 mg/(kg day)	Hinchee and Smith, 1991

[a] Rates reported by Hinchee et al., (1991) were first order with respect to oxygen; for comparative purposes, these have been converted to zero order with respect to hydrocarbons at an assumed oxygen concentration of 10%.

[b] Rates were reported as oxygen consumption rates; these have been converted to hydrocarbon degradation rates assuming a 3:1 oxygen-to-hydrocarbon ratio.

[c] Units are in kilograms of hydrocarbon degraded per 30 standard cubic feet per minute (scfm) extraction vent well per day.

In the case of the higher pH and higher alkalinity soils at Fallon NAS and Eielson AFB, little or no gaseous CO_2 production was measured (Hinchee et al., 1991b). This could be due to the formation of carbonates from the gaseous evolution of CO_2 produced by biodegradation at these sites. A similar problem was encountered by van Eyk and Vreeken (1988) in their attempt to use CO_2 evolution to quantify biodegradation associated with soil venting.

3.0 IN SITU RESPIRATION/AIR PERMEABILITY TEST PREPARATION

The necessary preparation, procedures, and specific tasks to conduct the in situ respiration/air permeability test are presented in the following subsections. Figure 3-1 shows a generalized flow chart of the process.

3.1 Site Characterization Review

To initiate site characterization, the project officer will inform the contractor of the Air Force facilities and specific sites where these tests will be conducted. The project officer will also provide a contact person at each Air Force facility (hereafter called base point-of-contact, or base POC). The project officer and/or the base POC will supply any relevant documents (site characterization reports, underground utility drawings, remedial investigation/feasibility studies, etc.) pertaining to the contaminated area.

A tentative test site will be selected after reviewing all preliminary documents and consulting with the project officer and the base POC. Final approval of the test area will be obtained from the project officer.

3.2 Development of Site-Specific Test Plan

All involved parties for a given site will be provided with a site-specific test plan. The site-specific test plan will consist of this generic test plan with a site-specific cover letter. The following information will typically be provided in the cover letter:

- A map showing the chosen test location, and if possible, tentative vent well and monitoring point locations
- Construction details for tentative vent well and monitoring points
- Details of any required permits and actions taken to obtain the permits
- Estimated field start date
- Any anticipated deviations from the generic test plan
- Site-specific support required from the base
- Site-specific health and safety requirements, if required.

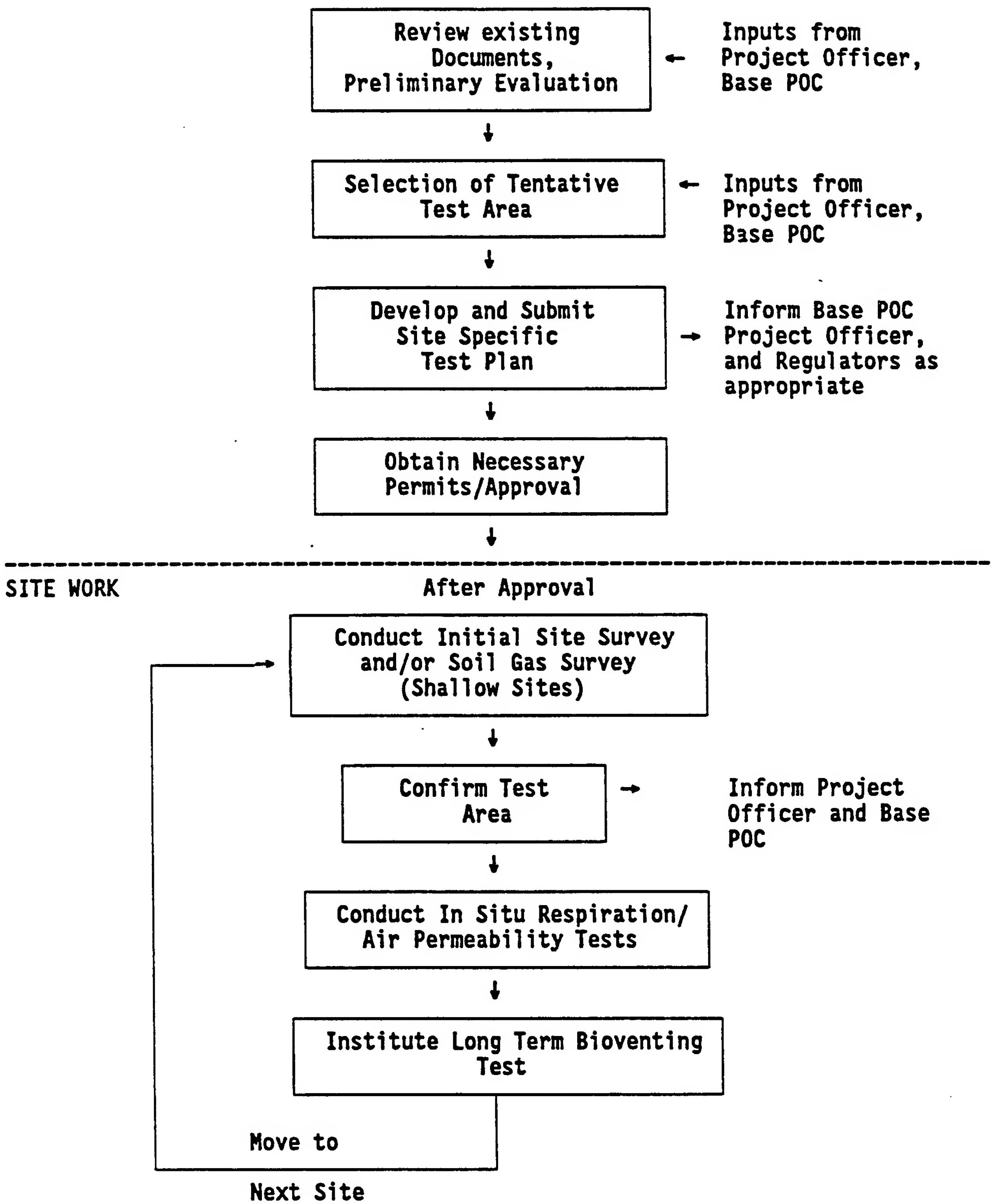

Figure 3-1. Flow Chart for Conducting Bioventing Treatability Test.

The site-specific test plan will be submitted to the project officer, base POC, and any necessary regulatory agencies for approval. The test plan will normally be submitted to outside regulatory agencies by either the project officer or the base POC. Unless specifically directed otherwise by the project officer, the contractor will not directly contact regulatory agencies or submit plans to them. No site work will be initiated without the necessary approval.

3.3 Application for Required Permits

As soon as a candidate site is identified by the Air Force project officer, applications must be submitted for the required permits. Obtaining permits frequently is the greatest holdup in accomplishing this type of field work. It is likely that no state or local permits will be required, but this must be determined early. Types of permits that may be required include:

- Drilling and/or well installation permits for the vent well and/or monitoring points
- Air Emission Permit for the vent well if air is extracted.
- Site Investigation Permit or Approval. This usually will not be necessary; however, some regulatory jurisdictions may require permitting. This test should not normally be considered a CERCLA treatability test.

No direct contact will be made by the contractor with regulatory agencies without project officer and base POC approval. In many cases the project officer or base POC will handle regulatory contacts, if they are necessary.

The contractor will coordinate with the base POC to obtain access and necessary clearance to conduct the tests at the candidate test area. The contractor will arrange with the base for the utilities — electricity and water — needed to execute the tests. If electricity is not available, the contractor will provide power from portable generators. The contractor will coordinate with the base POC to obtain any necessary security clearances or badges.

As early as possible, the contractor will supply the base POC with a list of all personnel to be used on base, including name, social security number, place and date of birth, and expected arrival date. The contractor will also request that the base POC initiate the process of obtaining a digging permit.

4.0 TEST WELLS AND EQUIPMENT

This section describes the test wells and equipment that are required to conduct the field treatability tests. It must be recognized that site-specific flexibility will be required, and thus, details will vary. Local and/or state regulatory agencies and at times individual Air Force bases will have specific requirements that differ from specifications in this test plan. All testing must comply with regulations, and must be acceptable to the host base.

Field notes will be maintained describing all vent well and monitoring point construction. Deviations from standard design will be noted in the final report.

4.1 Vent Wells

A vent well and blower system will be established to provide airflow through the subsurface, creating a pressure/vacuum gradient for air permeability testing and increasing subsurface oxygen levels for in situ respiration testing. This 2- to 4-in. vent well will be placed with the screened section in contaminated soil and will be located near the center of the fuel spill. The siting and construction of the venting well will follow these general criteria:

1. The vent well will be sited as near to the center of the spill area as possible. This location will ensure that data gathered from the test will be as representative as possible of contaminated soil conditions. On many small sites, the vent well used during the treatability test can be converted into the primary vent well for extended testing.

2. The diameter of the vent well may vary between 2 and 4 in. and will depend on the ease of drilling and the area and depth of the contaminated volume. On most sites a 2-in.-diameter vent will provide adequate airflow for air permeability/radius of influence testing. For sites with contamination extending below 30 ft, a 3- or 4-in. vent well is recommended. The cost of a larger well is a minor component of the total drilling cost because a drill rig will be required to drill to this depth, regardless of well diameter. Groundwater monitoring points screened several ft above the existing water table can also be converted to vent wells. This option is appropriate for air injection systems but will be less successful for air extraction systems because the applied vacuum will cause a rise in the water table which could rapidly submerge the screened interval.

3. The vent well will normally be constructed of schedule 40 polyvinyl chloride (PVC), and will be screened with a slot size that maximizes airflow through the soil. The screened interval will extend through as much of the contaminated profile as possible, with the bottom of the screen corresponding to the top of the capillary fringe. For shallow sites with groundwater less than 20 ft deep, the vent well will be screened over the bottom half of the unsaturated zone. For deeper wells, care must be taken in determining the depth of the top of the screen. A deeper screen is normally better. If the top of the screen is close to the ground surface, much of the airflow may follow the shortest path from near the top of the screen to the ground surface.

4. Hollow-stem augering is the recommended drilling method; however, a solid-stem auger is also acceptable in more cohesive soils. Whenever possible, the diameter of the annular space will be at least two times greater than the vent well outside diameter. The annular space corresponding to the screened interval will be filled with silica sand or equivalent. In shallow softer soils, hand-augering may be feasible. The annular space above the screened interval will be sealed with wet bentonite and grout to prevent short-circuiting of air to or from the surface. Figure 4-1 shows a typical vent well.

4.2 Soil Gas Monitoring Points

Soil gas monitoring points will be used for pressure and soil gas measurements and will be installed at a minimum of three locations, and at each location to at least three depths. The total number will vary, with up to six monitoring point locations, and six or more depths, depending on site conditions.

To the extent possible, the monitoring points will be located in contaminated soils with >1,000 mg/kg of total petroleum hydrocarbon. These soils will have a strong odor and will feel oily to the touch. It may not be possible to locate all monitoring points in contaminated soil, especially the points furthest from the vent well. If this is the case, it is important to ensure that the point closest to the vent well be located in contaminated soil, and if possible, the intermediate point be placed in contaminated soils. If no monitoring points are located in contaminated soil, no meaningful in situ respiration test can be conducted. If the initial oxygen levels in the soil gas are not low, i.e., below 2 to 5%, and the soil gas hydrocarbon levels are not high, say above 10,000 ppm for relatively fresh JP-4 fuel, the monitoring point may not be suitable for an in situ respiration test.

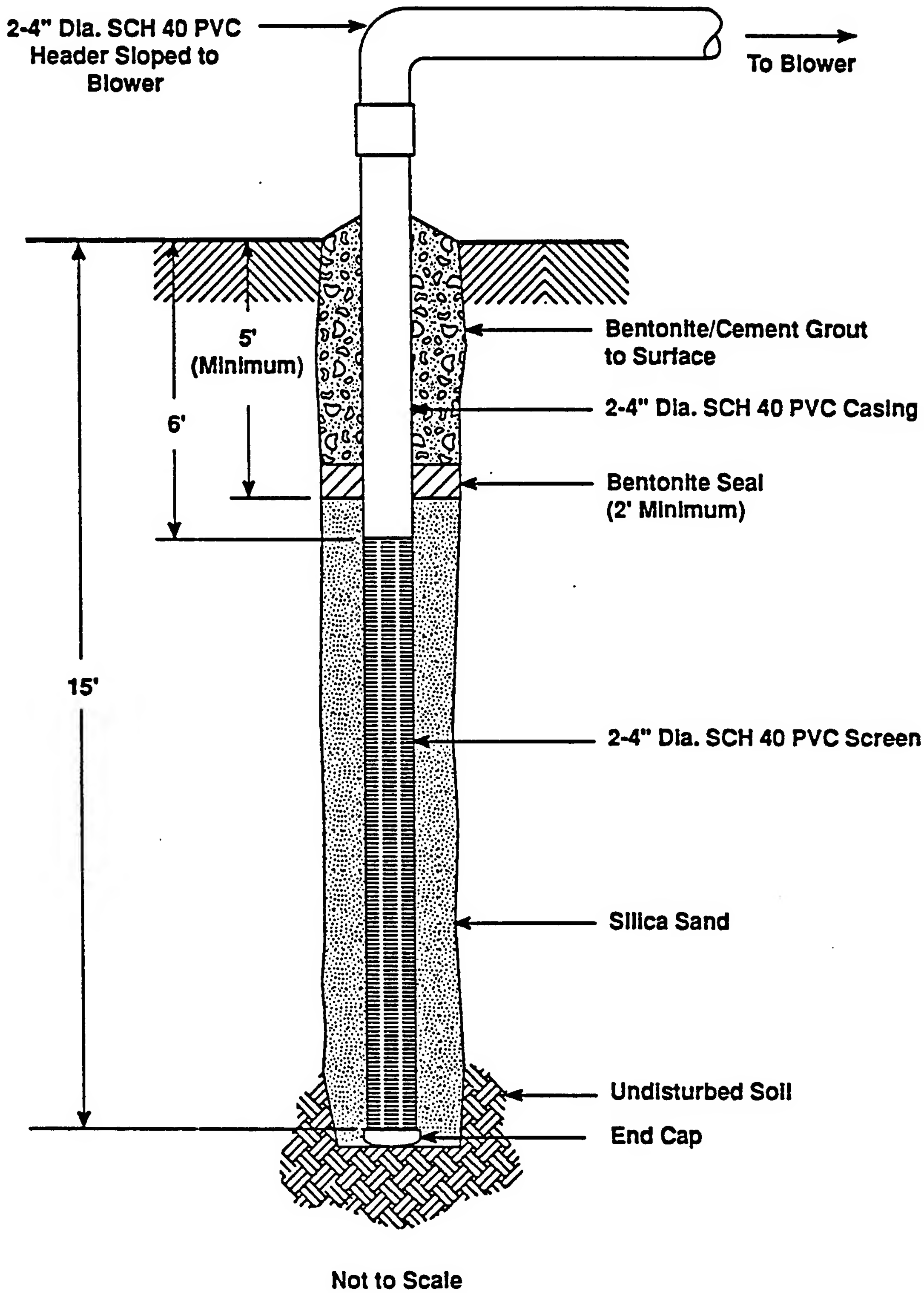

Figure 4-1. Typical Injection/Vacuum Venting Well Construction.

Higher oxygen concentrations would indicate that the microbial activity is not oxygen-limited or that there is sufficient exchange of air with the atmosphere to keep the soil gas well-aerated. In either case, bioventing will not increase biodegradation rates. At some sites, where less contaminated soils and low O_2 concentrations are encountered, bioventing may still be feasible. If these conditions are found, care must be taken to place the monitoring points in the most contaminated soil possible.

4.2.1 Location of Monitoring Points

A minimum of 3 monitoring points is recommended; ideally these will be in a straight line and at the intervals recommended in Table 4-1. In an unobstructed heterogeneous site, 3 monitoring points at these spacings are appropriate. Additional monitoring point locations may be necessary for a variety of site-specific reasons including, but not limited to, spatial heterogeneities, obstructions, or the desire to monitor a specific location. Additional discussion related to monitoring point placement is found in Section 5.0, Test Procedures.

4.2.2 Depth of Monitoring Points

In general, each monitoring point will be screened to at least 3 depths. The deepest screen will be placed either at or near the bottom of contamination if a water table is not encountered, or a minimum of 2 to 3 ft above the water table if it is encountered. Consideration will be given to potential seasonal water table fluctuations and soil type in finalizing the depth. In a more permeable soil the monitoring point can be screened closer to the water table. In a less permeable soil it must be screened further above the water table. The shallowest screen will normally be 3 to 5 ft below land surface. The intermediate screen will be placed at a reasonable interval at a depth corresponding to the center to upper ¼ of the depth of the vent well screen.

As an example, in a sandy soil with groundwater at 30 ft and a vent well screened from 17.5 to 27.5 ft below land surface, reasonable screened depths for the monitoring points would be 28 ft, 22.5 ft, and 3 ft. For sites with vent wells deeper than 30 ft, more depths may be screened, depending on stratigraphy.

It will be necessary in some cases to add additional screened depths to ensure a well-oiled soil is encountered, to monitor differing stratigraphic intervals, or to adequately monitor deeper sites with broadly screened vent wells. If air injection is being considered in the bioventing test, a monitoring point must be located between the vent well and any buildings that may be at risk to assure that they are well beyond the radius of influence.

TABLE 4-1. Recommended Spacing for Monitoring Points

Soil Type	Depth to Top of Vent Well Screen (ft)(1)	Spacing Interval (ft)(2)
Coarse Sand	5	5-10-20
	10	10-20-40
	>15	20-30-60
Medium Sand	5	10-20-30
	10	15-25-40
	>15	20-40-60
Fine Sand	5	10-20-40
	10	15-30-60
	>15	20-40-80
Silts	5	10-20-40
	10	15-30-60
	>15	20-40-80
Clays	5	10-20-30
	10	10-20-40
	>15	15-30-60

(1) Assuming 10 ft of vent well screen, if more screen is used, the >15-ft spacing will be used.

(2) Note that monitoring point intervals are based on a venting flow rate range of 1 cfm/ft screened interval for clays to 3 cfm/ft screened interval for coarse sands.

4.2.3 Construction of Monitoring Points

Most state and local regulatory agencies do not regulate unsaturated zone soil gas monitoring point construction. Nevertheless, prior to construction it is necessary to check with regulators to assure compliance with any regulations that may exist.

Monitoring point construction will vary depending on the depth of drilling and the drilling technique. Basically, the monitoring points will consist of a small-diameter ¼-in. tube to the specified depth with a screen approximately 6 in. long and ½ to 1 in. in diameter. In shallow hand-augered installations, rigid tubing (i.e., Schedule 80 ¼" PVC) terminating in the center of a gravel or sand pack may be adequate. The gravel or sand pack will normally extend for an interval of 1 to 2 ft with the screen centered. In low-permeability soils, a larger gravel pack may be desirable. In wet soils a longer gravel pack with the screen near the top may be desirable. A bentonite seal at least 2 ft thick is normally required above and below the gravel pack. Figure 4-2 shows a typical installation.

For relatively shallow installations in more permeable soils, a hand-driven system, such as that of KVA Associates, may be used. In such a system, a sacrificial drive point with Tygon™, Teflon™, or other appropriate tubing is driven to the desired depth. Then, the steel outer tubing is retrieved, leaving the drive point and the inner flexible tubing in place. Because this type of installation allows little or no sand pack or seal placement, it should be used only in relatively permeable soils where sample collection will not be a problem or in soils that will "self heal" to prevent short-circuiting. Surface completion of the hand-driven points should be the same as for those installed in borings.

Tubes will be used to collect soil gas for CO_2 and O_2 analysis in the 0.25% range, and for JP-4 hydrocarbons in the 100 ppm range or higher. The tubing material must have sufficient strength and be nonreactive. Sorption and gas interaction with the tubing materials have not been significant problems for this application. If a monitoring point will be used to monitor specific organics in the low ppm or ppb range, teflon or stainless steel may be necessary. However, this will not normally be the case.

All tubing from each monitoring point will be finished with quick-connect couplings and will be labeled twice. Each screened depth will be labeled as follows:

[Code for Site] — [Code for Monitoring Point] — [Depth to Center of Screened Interval].

Table 4-2 lists the labels used for example site #2 at Millersworth AFB. In M2, the M is for Millersworth AFB, and the 2 is for site #2 at Millersworth. The tubing will be labeled with a firmly attached metal tag or directly by engraving or in waterproof ink. Instead of a metal tag, a metal plate may be placed at the bottom of the monitoring point compartment with holes drilled for each tube. The metal plate will then be engraved, identifying each tube where it passes through the plate. If this method is used, the tube itself must still be labeled with ink or by engraving. The label will be placed close to the ground so that, if the tube is damaged, the label is likely to survive.

The top of each monitoring point will be labeled to be visible from above. This will be done either by writing in the concrete or with spray paint.

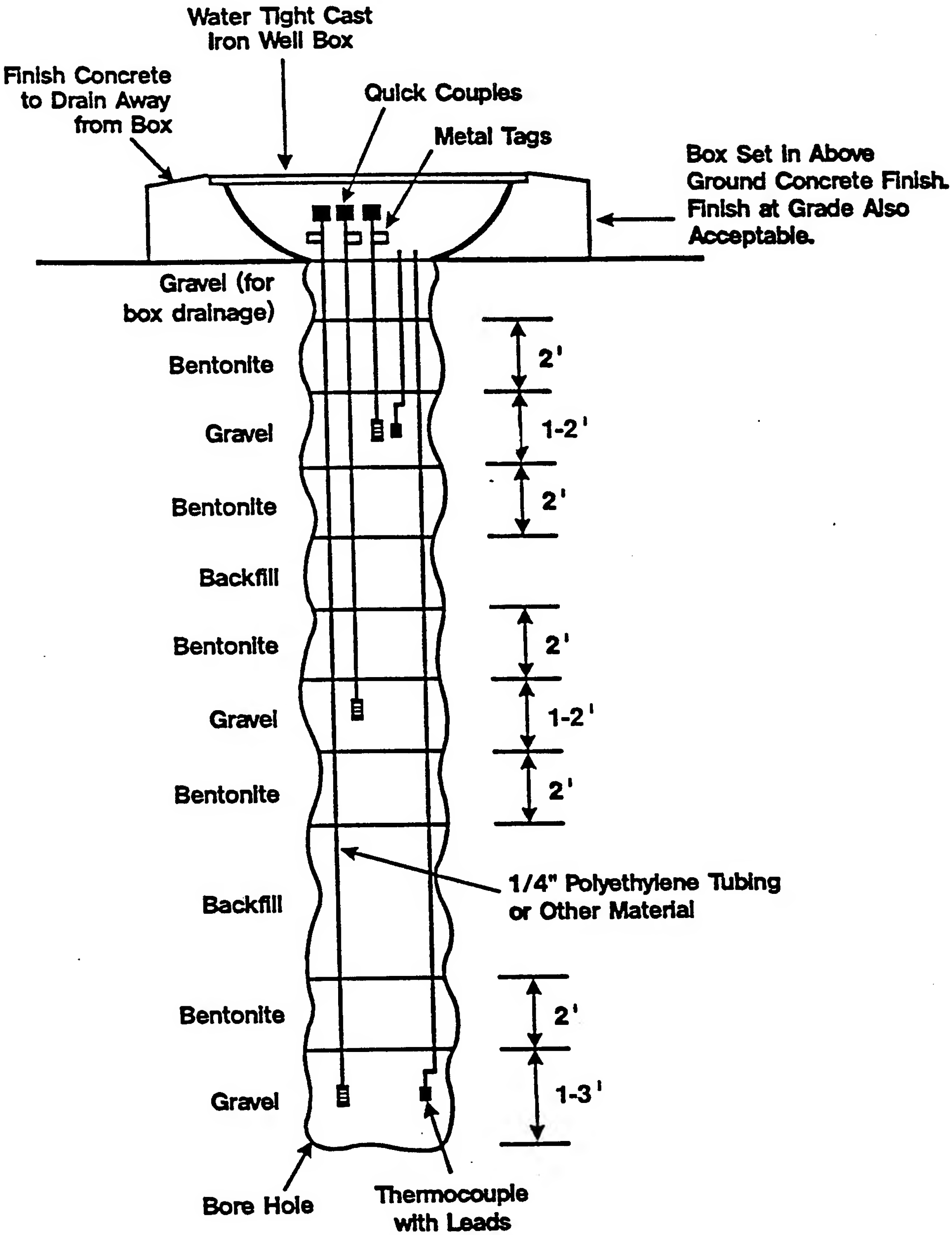

Figure 4-2. Typical Monitoring Point Construction Detail.
(Dimensions will vary for specific installations.)

TABLE 4-2. Monitoring Points for Example Site #2 at Millersworth AFB

M2-A-3	(3 ft deep)	Monitoring Point A, Closest to the vent well
M2-A-15	(15 ft deep)	
M2-A-25	(25 ft deep)	
M2-B-3	(3 ft deep)	Monitoring Point B, Intermediate from vent well
M2-B-15	(15 ft deep)	
M2-B-27	(27 ft deep)	
M2-C-3	(3 ft deep)	Monitoring Point C, Farthest from vent well
M2-C-14	(14 ft deep)	
M2-C-23	(23 ft deep)	

The monitoring points will be finished by placement in a watertight cast iron well box. The well box will be placed either aboveground in a concrete pad or at grade, also in concrete. The box will be drained to prevent water accumulation.

4.2.4 Thermocouples

Two thermocouples will be installed at each site. They will be installed at the monitoring point closest to the vent well and, as shown in Figure 4-2, at the depth of the shallowest and deepest screen. Thermocouples used are either J or K type. The thermocouple wires will be labeled using the same system as for the tubings, except that a two-letter word, TC, will be added to the identification label (e.g., M2-TCA-3, for the thermocouple installed at the second Millersworth AFB site monitoring point A at the 3-ft depth).

4.3 Background Well

In addition to the vent well and the monitoring points installed in contaminated soils, a background well will be installed in uncontaminated soil to monitor the background respiration of natural organic matter. Soil gas in uncontaminated soil generally has O_2 levels between 15 and 20% and CO_2 levels between 1 and 5%. The background well will be similar in construction to the vent well (Figure 4-1), except that the length of the screen will be approximately 5 ft.

To the extent possible, the screen of the background well will be located at a depth similar to that of the monitoring points and in the same stratigraphic formation. For

sites deeper than 20 ft, the screen portion of the background well will be placed at 20 to 25 feet. For depths less than 20 ft, the screen portion of the background well will be placed between 5 and 15 ft.

4.4 Blower System

The type and size of blower used on a test site will be determined based upon the soil type, depth and area of contamination, and available power. In an attempt to reduce the number of blower units in the pilot test inventory and to standardize piping and instrumentation, two typical blowers are specified:

Blower One

Application:
Contaminated interval in sandy soils and mixed sandy/silt and sandy/clay soils.

Typical Specifications:
- Explosion-proof regenerative blower
- 20 to 90 scfm at 20" to 100" H_2O, respectively
- 3-HP explosion-proof motor
- Single-phase 230-V power source

Blower Two

Application:
Predominantly silt and clay soils.

Typical Specifications:
- Explosion-proof pneumatic blower
- 50 scfm at 130" H_2O.
- 5-HP explosion-proof motor
- Single-phase 230-V power source.

Each blower will be fitted with mounting brackets and pipe fittings to make it compatible with the basic blower systems shown in Figures 4-3 and 4-4. Explosion-proof blowers and motors are required when soil gas extraction is used. Explosion-proof equipment may be required for air injection systems as well.

The blower system will be instrumented to monitor blower performance and to provide test data such as the vent well pressure (Pw) and the gas stream flow rate (Q) adjusted for air density. Using these data and pressure data from each soil gas monitoring point, k and R_I can be estimated.

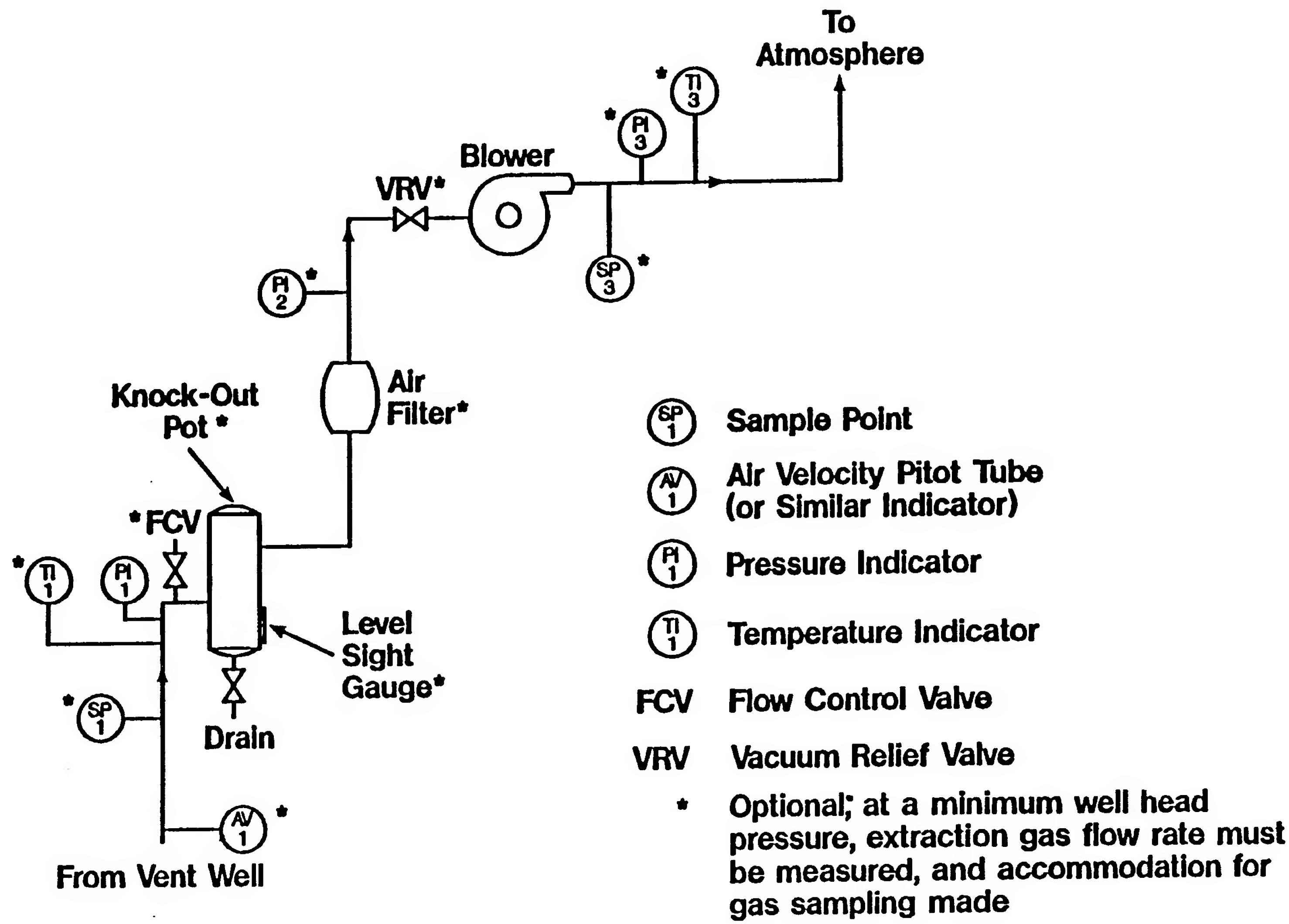

Figure 4-3. Soil Gas Permeability Blower System Instrumentation Diagram for Soil Gas Extraction.

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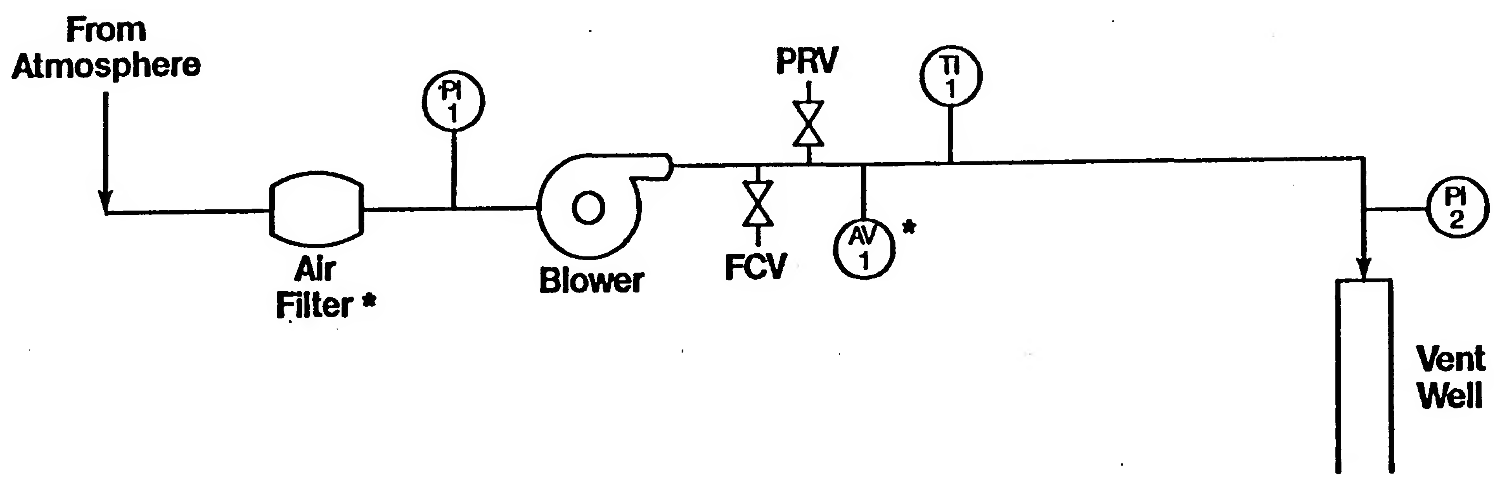

AV 1 Air Velocity Pitot Tube (or Similar Indicator)

PI 1 Pressure Indicator

TI 1 Temperature Indicator

FCV Flow Control Valve

PRV Pressure Relief Valve

* Optional

Figure 4-4. Soil Gas Permeability Blower System Instrumentation Diagram for Air Injection.

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4.5 Field Instrumentation and Measurements

Sections 4.5.1 through 4.5.6 discuss the equipment used for measurements. Figures supplement the text.

4.5.1 Oxygen and Carbon Dioxide

Gaseous concentrations of CO_2 and O_2 will be analyzed using a GasTech model 3252OX CO_2/O_2 analyzer or equivalent. The battery charge level will be checked to ensure proper operation. The air filters will be checked and, if necessary, cleaned or replaced before the experiment is started. The instrument will be turned on and equilibrated for at least 30 minutes before conducting calibration or obtaining measurements. The sampling pump of the instrument will be checked to ensure that it is functioning. Low flow of the sampling pump can indicate that the battery level is low or that some fines are trapped in the pump or tubing.

Meters will be calibrated each day prior to use against purchased CO_2 and O_2 calibration standards. These standards will be selected to be in the concentration range of the soil gas to be sampled. The CO_2 calibration will be performed against atmospheric CO_2 (0.05%) and a 5% standard. The O_2 will be calibrated using atmospheric O_2 (20.9%) and against a 5% and 0% standard. Standard gases will be purchased from a specialty gas supplier. To calibrate the instrument with standard gases, a Tedlar™ bag (capacity ~1 l) is filled with the standard gas, and the valve on the bag is closed. The inlet nozzle of the instrument is connected to the Tedlar™ bag, and the valve on the bag is opened (see Figure 4-5). The instrument is then calibrated against the standard gas according to the manufacturer's instructions. Next, the inlet nozzle of the instrument is disconnected from the Tedlar™ bag and the valve on the bag is shut off. The instrument will be rechecked against atmospheric concentration. If recalibration is required, the above steps will be repeated.

4.5.2 Hydrocarbon Concentration

Petroleum hydrocarbon concentrations will be analyzed using a GasTech Trace-Techtor™ hydrocarbon analyzer (or equivalent) with range settings of 100 ppm, 1,000 ppm, and 10,000 ppm. The analyzer will be calibrated against two hexane calibration gases (500 ppm and 4,400 ppm). The Trace-Techtor™ has a dilution fitting that can be used to calibrate the instrument in the low-concentration range.

Calibration of the GasTech Trace-Techtor™ is similar to the GasTech Model 32402X, except that a mylar bag is used instead of a Tedlar™ bag. The O_2 concentration must be above 10% for the Trace-Techtor™ analyzer to be accurate. When the O_2 drops below 10%, a dilution fitting must be added to provide adequate oxygen for analysis.

Hydrocarbon concentrations can also be determined with a flame ionization detector (FID), which can detect low (below 100 ppm) concentrations. A photoionization detector (PID) is *not* acceptable.

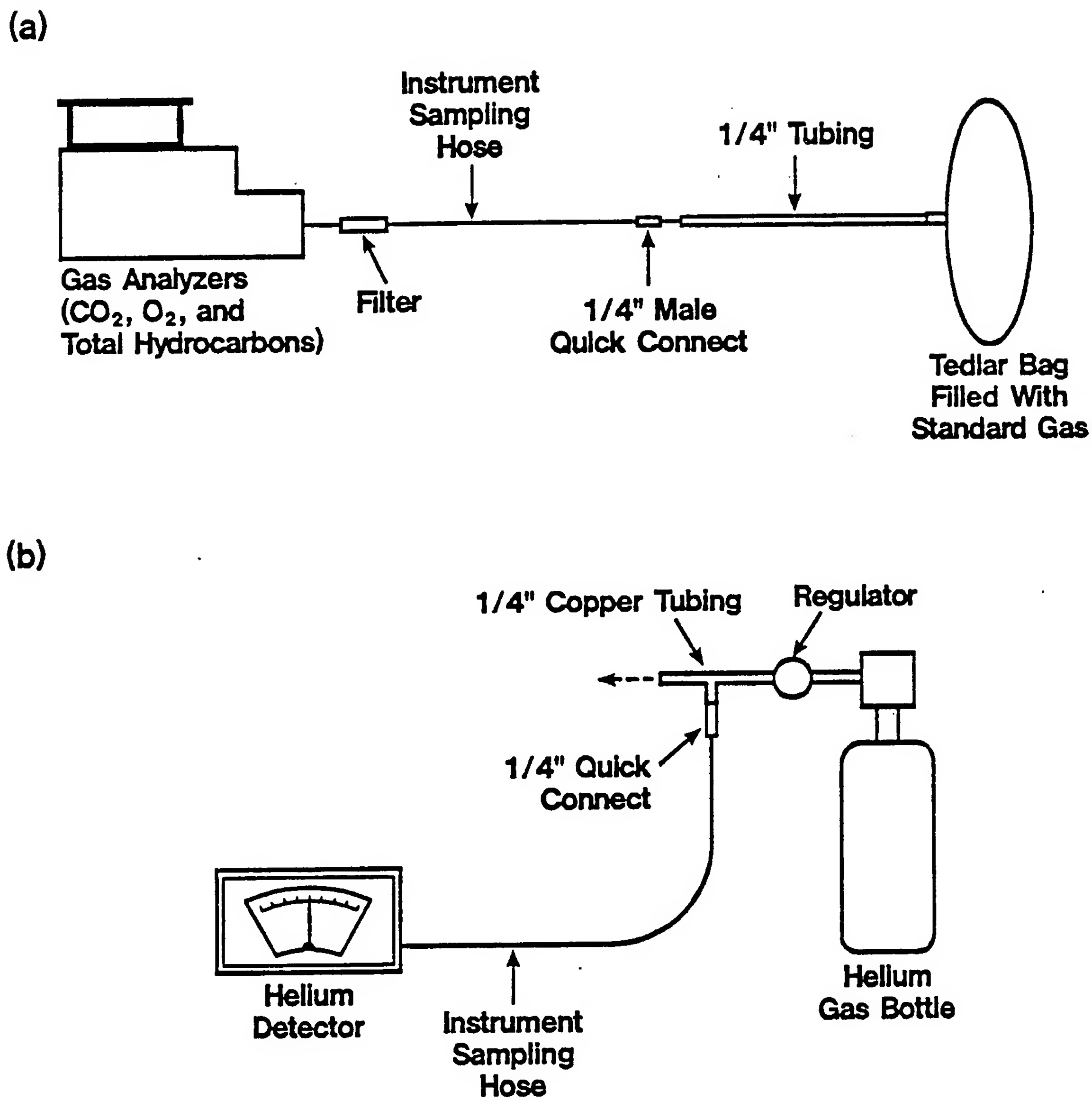

Figure 4-5. Schematic Setup for Calibration of Soil Gas Instruments.
(a) CO_2, O_2, and Total Hydrocarbon Analyzers.
(b) Helium Detector.

4.5.3 Helium Monitoring

Helium in the soil gas will be measured with a Marks Helium Detector Model 9821 or equivalent with a minimum sensitivity of 100 ppm (0.01%). Calibration of the helium detector follows the same basic procedure described for oxygen calibration, except that the setup for calibration is different (see Figure 4-5). Helium standards used are 100 ppm (0.01%), 5,000 ppm (0.5%), and 10,000 ppm (1%).

4.5.4 Temperature Monitoring

In situ soil temperature will be monitored using Omega Type J or K thermocouples (or equivalent). The thermocouples will be connected to an Omega OM-400 Thermocouple Thermometer (or equivalent). Each thermocouple will be calibrated against ice water and boiling water by the contractor before field installation.

4.5.5 Pressure/Vacuum Monitoring

Changes in soil gas pressure during the air permeability test will be measured at monitoring points using Magnehelic™ or equivalent gauges. Tygon™ or equivalent tubing will be used to connect the pressure/vacuum gauge to the quick-disconnect on the top of each monitoring point. Similar gauges will be positioned before and after the blower unit to measure pressure at the blower and at the head of the venting well. Pressure gauges are available in a variety of pressure ranges, and the same gauge can be used to measure either positive or negative (vacuum) pressure by simply switching inlet ports. Gauges are sealed and calibrated at the factory and will be rezeroed before each test. The following pressure ranges (in inches H_2O) will typically be available for this field test:

0-1", 0-5", 0-10", 0-20", 0-50", 0-100", and 0-200"

Air pressure during injection for the in situ respiration test will be measured with a pressure gauge with a minimum range of 0 to 30 psig.

4.5.6 Airflow

Airflow measurements will be taken for both the air permeability test and the respiration test. These measurements are described in Sections 4.5.6.1 and 4.5.6.2.

4.5.6.1 Airflow Measurement — Air Permeability Test

During the air permeability test an accurate estimate of flow (Q) entering or exiting the vent well is required to determine k and R_I. Several airflow measuring devices are acceptable for this test procedure.

Pitot tubes or orifice plates combined with an inclined manometer or differential pressure gauge are acceptable for measuring flow velocities of 1,000 ft/min or greater (~20 scfm in a 2-in. pipe). For lower flow rates, a large rotometer will provide a more accurate measurement. If an inclined manometer is used, the manometer must be rezeroed before and after the test to account for thermal expansion/contraction of the water. Devices to measure static and dynamic pressure must also be installed in straight pipe sections according to manufacturer's specifications. All flow rates will be corrected to standard temperature and ambient pressure (altitude) conditions.

4.5.6.2 Airflow Measurement — Respiration Test

Prior to initiating respiration tests at individual monitoring points, air will be pumped into each monitoring point using a small air compressor as described in Section 5.7. Airflow rates of 1 to 1.5 cfm will be used, and flow will be measured using a Cole-Palmer Variable Area Flowmeter No. N03291-4 (or equivalent). Helium will be introduced into the injected air at a 1% concentration. A helium flow rate of approximately 0.01 to 0.015 cfm (0.6 to 1.0 cfh) will be required to achieve this concentration. A Cole-Palmer Model L-03291-00 flowmeter or equivalent will be used to measure the flow rate of the helium feed stream.

4.5.6.3 Airflow Measurement — Bioventing Test

Airflow measurements during the bioventing tests may be made as described for the air permeability test (Section 4.5.6.1). If a single vent well and blower are used and 100% of the flow to the blower comes from the extraction well, the air flow measurement may not be necessary. If a blower with a known pump curve is used and intake and exhaust pressures are monitored, flow rate can be estimated from the pump curve.

5.0 TEST PROCEDURES

5.1 Location of Optimum Test Area

A soil gas survey will be conducted to locate an optimum site for the vent well and the soil gas monitoring points. Ideally, the vent well and monitoring points will be located in well-oiled soils where the O_2 is depleted and the CO_2 levels are elevated (see discussion in 4.2). If at least three monitoring point screens are not located in the most contaminated soils, then the in situ respiration test may not provide adequate information on the biodegradation rates for the site.

5.1.1 Soil Gas Survey (for contamination < 20 ft)

A soil gas survey will be conducted prior to locating the vent well and monitoring points at sites with relatively shallow groundwater where soils are penetrable to a depth of within 5 ft of the water table using hand-driven gas probes. The survey will not be a complete site soil gas survey to fully delineate contamination.

Accessibility to the site will be confirmed, along with possible restrictions that may hamper the tests. Existing groundwater and soil gas monitoring wells near the test area will be identified. Groundwater will be checked for free floating product, and soil gas from any existing monitoring points or wells will be analyzed for O_2, CO_2, and total hydrocarbons before proceeding with the soil gas survey. To assist in the soil gas survey, a simple sampling grid will be established using existing monitoring wells or prominent landmarks for identification.

Soil gas sampling will be conducted using small-diameter (~5/8-inch OD) stainless steel probes (KVA Associates or equivalent) with a slotted well point assembly. The maximum depth for hand-driven probes will typically be 10 to 15 ft, depending on soil texture. In some dense silts or clays, penetration of the soil gas probe will be less, while in some unconsolidated sands, deeper penetration may be possible. At a given location on the grid, a probe will be driven (manually or with a power hammer) to a depth determined by preliminary review of the site contamination documents. Soil gas at this depth will be analyzed for O_2, CO_2, and total hydrocarbons. The probe will then be driven deeper, and the soil gas will be measured. For a typical site with a depth to groundwater of 9 ft, soil gas will be measured at depths of 2.5 ft, 5 ft, and 7.5 ft.

The main criterion for selecting a suitable test site is that the microbial activity should be oxygen-limited. Under such conditions, the O_2 level will be low (usually 0 to 2%), CO_2 will be high (typically 5 to 20%, depending on soil type), and hydrocarbon content will be high (> 10,000 ppm for most fresh JP-4 sites).

An uncontaminated site also will be located to be used as an experimental control to monitor background respiration of natural organic matter and inorganic sources of CO_2.

Typical O_2 and CO_2 levels at an uncontaminated site are 15 to 20% and 1 to 5%, respectively. The hydrocarbon content in the soil gas of a contaminated site is generally below 100 ppm.

Prior to sampling, soil gas probes will be purged with a sample pump. To determine adequate purging time, soil gas concentrations will be monitored until the concentrations stabilize. This will not always be possible, particularly when shallow soil gas samples are being collected, as atmospheric air may be drawn into the probe and produce false readings. When shallow soil gas samples are collected, air withdrawal will be kept to a minimum. Figure 5-1 shows a typical setup for monitoring soil gas.

5.1.2 Exploratory Boring in Deep Soils

On sites where contamination extends to depths greater than 20 ft, exploratory borings will be used to ensure that the vent well and monitoring points are located in fuel-contaminated soils. Exploratory borings that encounter significant fuel contamination will then be completed and used as vent wells or monitoring points.

A hollow-stem auger will be used to advance the boring, and drill cuttings will be visually checked and analyzed with a GasTech Trace-Techtor™ (or equivalent) hydrocarbon analyzer, an equivalent explosimeter, or a FID, to determine the relative fuel contamination of each 2- to 3-ft interval. Drill cuttings will be inspected at each contaminated interval selected for monitoring point installations.

As the boring advances beyond 20 ft, a split-spoon sampling device will be recommended for sampling at 5-ft intervals. Split-spoon samples will be visually checked for fuel contamination and screened for volatile emissions by passing a hydrocarbon analyzer slowly over the open split spoon.

The purpose of this simple monitoring technique will be to provide air monitoring for worker health and safety, to rapidly locate the interval of highest contamination, and to attempt to locate the maximum depth of contamination at each site. A geologic driller's log will be kept to identify changes in lithology, depths of apparent fuel contamination, and sample locations. Exploratory borings will also be required to locate a clean area for installing the background monitoring point. Careful inspection of drill cuttings and volatile hydrocarbon monitoring will be required to ensure that soils in the control area are free of fuel hydrocarbons.

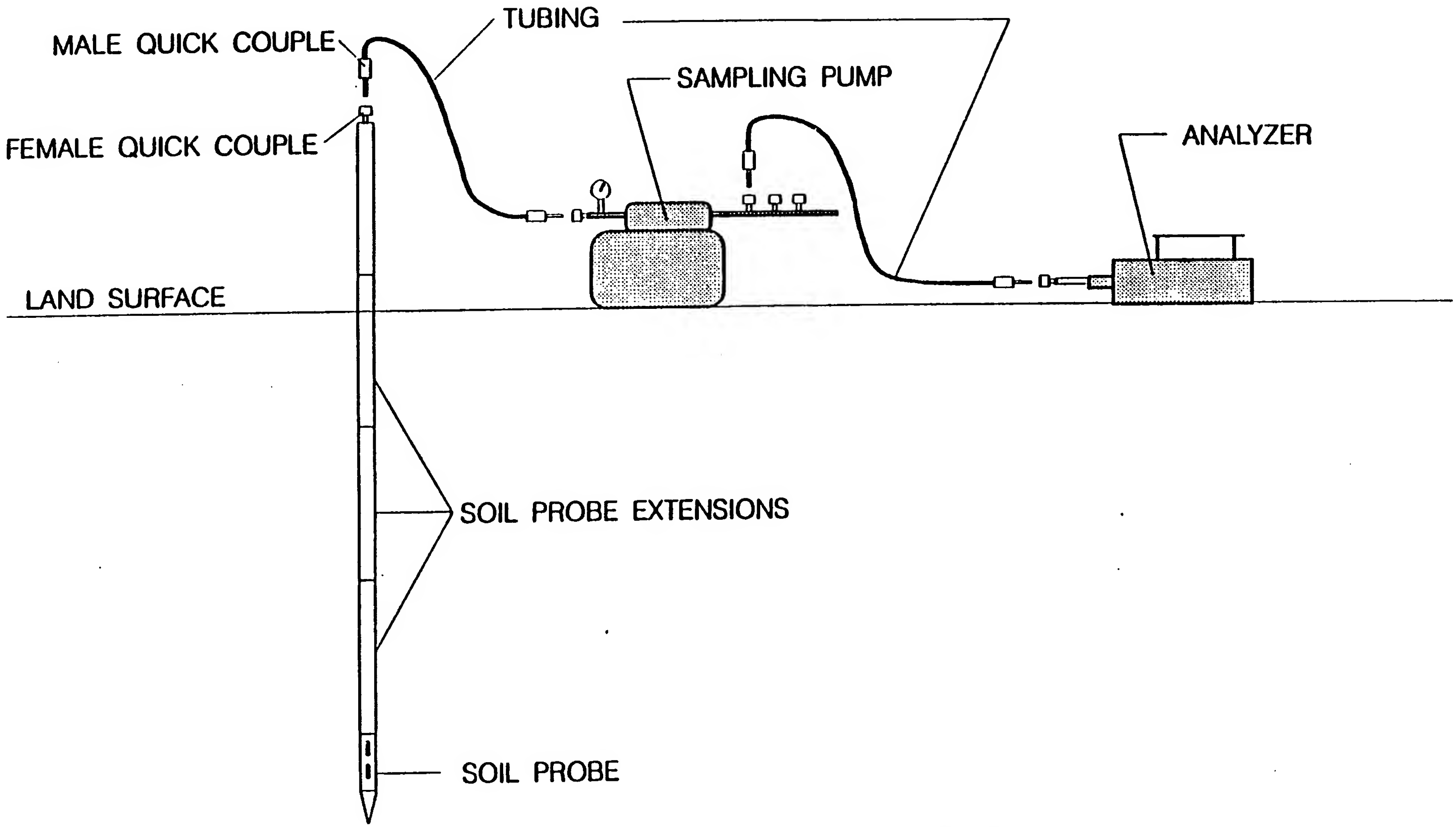

Figure 5-1. Schematic Diagram of Soil Gas Sampling Using the Stainless Steel Soil Gas Probe.

5.2 Drilling and Installation of the Vent Well

Based on a review of available site characterization data, a preliminary location will be proposed for the vent well. Following the soil gas survey and/or exploratory boring, a final vent well location will be determined. If soils were proved to be sufficiently contaminated, the exploratory boring will be completed as the vent well. Soil samples will be collected at a minimum interval of 5 ft in the vent well boring following the procedures outlined in Section 5.5. Siting and construction of the vent well will follow the criteria provided in Section 4.1.

5.3 Drilling and Installation of Monitoring Points

Based on the location of the vent well and available site characterization data, the monitoring points will be located at points where sufficient data for the air permeability tests can be obtained and, at the same time, they can be used for the in situ respiration test. Table 4-1 will be used as a guide to locate the monitoring points in relation to the location of the vent well. The location of the monitoring points will also take into consideration the long-term bioventing test that will be conducted after the in situ respiration test. The monitoring points will generally be located in a contaminated area. Screens for the monitoring points will have the same slot sizes as those for the vent well (see discussion in Section 4.2).

When possible, the monitoring points will be placed in hand-augered borings or in borings augered with a small portable drill. At deeper sites, it will be necessary to hire a driller for both the monitoring points and the vent well. When a drill rig is used, a hollow-stem auger will most likely be used. A smaller ID auger will be used, as required, for the vent well installation. Also as required, a solid auger will be used in shallow or cohesive soils.

5.4 Background Well Installation

A background well will be installed in an uncontaminated location to obtain soil gas measurements of O_2 and CO_2 concentrations to monitor background respiration. The well will be constructed in a manner similar to the vent well, except that it will normally be 1 in. in diameter with a screen length of 5 ft. At sites deeper than 20 ft, the screened portion of the background well will be placed at 20 to 25 ft, so long as it is screened in the same geological formation as the vent well. Normally, deeper screening will be required only if necessary to intercept the vented formation.

5.5 Collection of Soil Samples

A minimum of three to four soil samples will be collected from each site and analyzed for physical/chemical characteristics, including nutrient concentration. At least one representative sample of each contaminated soil type will be collected. It is important that samples for nutrient analyses be collected from a contaminated zone; otherwise, if fixation

has already occurred, the nitrogen concentration may not be representative. Soil samples will be collected from the exploratory boring or from the borings for the vent well or monitoring points. Soil samples will be collected from cuttings if the borings are shallow, by hand from a hand-augered hole, or with a split-spoon sampler. Enough soil will be collected to fill a 500-ml polyethylene or glass container. The container will be sealed with a teflon-lined cap and then placed in a cooler for shipment. Special procedures for preserving the sample will not be required, as only inorganics and the physical properties of the soil will be analyzed. Each soil sample will be labeled to identify the site, boring location and depth, and time of collection. Soil samples may also be collected for total petroleum hydrocarbon (TPH) analysis and for benzene, toluene, ethylbenzene, and xylene (BTEX) analysis. Samples to be used for TPH, BTEX, or any other volatility analysis must be collected, bundled, stored, and shipped in a manner that will prevent volatilization losses. The methods for this sampling are described in other sources.

Chain-of-custody forms will accompany each shipment to the laboratory. The soil samples will be analyzed for at least the following parameters:

- pH
- total kjeldahl nitrogen (TKN)
- total phosphorus
- alkalinity
- particle size analysis
- total iron
- moisture content.

In addition to the chain-of-custody forms, each sample will be logged into the project record book along with a complete description of where and how it was collected. Each sample will be labeled with an identification code corresponding to its sampling location. The code will follow the system described for labeling the monitoring points in Section 4.2.3 as follows:

[Code for Site] — [Code for Location] — [Depth]

Location codes will include the abbreviations VW for vent well, MP for monitoring point, BG for background well, or EB for an exploratory boring or other boring not completed as a vent well, monitoring point, or background well. For the example site #2 at Millersworth AFB the following codes might be used:

- M2—VW—12 for a sample from site #2 at Millersworth AFB from a depth of 12 ft from the vent well boring

- M2—MPC—28 for a sample from a depth of 28 ft from the monitoring point C boring

- M2–BG–4 for a sample from a depth of 4 ft from the background boring
- M2–EB2–20 for a sample from a depth of 20 ft from the second exploratory boring, which was subsequently grouted and not completed as a well or monitoring point.

5.6 Soil Gas Permeability Test Procedures

This section describes the field procedures that will be used to gather data to determine k and to estimate R_I. The Appendix provides an example data set and calculations for the radius of influence using the dynamic and steady-state solution methods.

Prior to initiating the soil gas permeability test, the site will be examined for any wells (or other structures) that will not be used in the test but may serve as vertical conduits for gas flow. These will be sealed to prevent short-circuiting and to ensure the validity of the soil gas permeability test.

5.6.1 System Check

Before proceeding with this test, soil gas samples will be collected from the vent well, the background well, and all monitoring points, and analyzed for O_2, CO_2, and volatile hydrocarbons. After the blower system has been connected to the vent well and the power has been hooked up, a brief system check will be performed to ensure proper operation of the blower and the pressure and airflow gauges, and to measure an initial pressure response at each monitoring point. This test is essential to ensure that the proper range of Magnehelic™ gauges are available for each monitoring point at the onset of the soil gas permeability test. Generally, a 10- to 15-minute period of air extraction or injection will be sufficient to predict the magnitude of the pressure response, and the ability of the blower to influence the test volume.

5.6.2 Soil Gas Permeability Test

After the system check, and when all monitoring point pressures have returned to zero, the soil gas permeability test will begin. Two people will be required during the initial hour of this test. One person will be responsible for reading the Magnehelic™ gauges, and the other person will be responsible for recording pressure (P′) vs. time on the example data sheet (see Appendix Table A-2). This will improve the consistency in reading the gauges and will reduce confusion. Typically, the following test sequence will be followed:

1. Connect the Magnehelic™ gauges to the top of each monitoring point with the stopcock opened. Return the gauges to zero.

2. Turn the blower unit on, and record the starting time to the nearest second.

3. At 1-minute intervals, record the pressure at each monitoring point beginning at t = 60 s.

4. After 10 minutes, extend the interval to 2 minutes. Return to the blower unit and record the pressure reading at the well head, the temperature readings, and the flow rate from the vent well.

5. After 20 minutes, measure P' at each monitoring point in 3-minute intervals. Continue to record all blower data at 3-minute intervals during the first hour of the test.

6. Continue to record monitoring point pressure data at 3-minute intervals until the 3-minute change in P' is less than 0.1 in. of H_2O. At this time, a 5- to 20-minute interval can be used. Review data to ensure accurate data were collected during the first 20 minutes. If the quality of these data is in question, turn off the blower, allow all monitoring points to return to zero pressure, and restart the test.

7. Begin to measure pressure at any groundwater monitoring points that have been converted to monitoring points. Record all readings, including zero readings and the time of the measurement. Record all blower data at 30-minute intervals.

8. Once the interval of pressure data collection has increased, collect soil gas samples from monitoring points and the blower exhaust (if extraction system), and analyze for O_2, CO_2, and hydrocarbons. Continue to gather pressure data for 4 to 8 hours. The test will normally be continued until the outermost monitoring point with a pressure reading does not increase by more than 10% over a 1-hour interval.

9. Calculate the values of k and R_I with the data from the completed test; use of the HyperVentilate™ computer program is recommended. The Appendix shows sample calculation methods for determining k and R_I.

5.6.3 Post-Permeability Test Soil Gas Monitoring

Immediately after completion of the permeability test, soil gas samples will be collected from the vent well, the background well, and all monitoring points, and analyzed for O_2, CO_2, and hydrocarbons. If the O_2 concentration in the vent well has increased by 5% or more, O_2 and CO_2 will be monitored in the vent well in a manner similar to that described for the monitoring points in the in situ respiration test. (Initial monitoring may be less frequent.) The monitoring will provide additional in situ respiration data for the site.

5.7 In Situ Respiration Test

The in situ respiration test will be conducted using four screened intervals of the monitoring points and a background well. The results from this test will determine if in situ microbial activity is occurring and if it is O_2-limited.

5.7.1 Test Implementation

Air with 1 to 2% helium will be injected into the monitoring points and background well. Following injection, the change of O_2, CO_2, total hydrocarbon, and helium in the soil gas will be measured over time. Helium will be used as an inert tracer gas to assess the extent of diffusion of soil gases within the aerated zone. If the background well is screened over an interval of greater than 10 ft, the required air injection rate may be too high to allow helium injection. The background monitoring point will be used to monitor natural degradation of organic matter in the soil. A schematic of the apparatus to be used in the in situ respiration test is presented in Figure 2-9.

The O_2, CO_2, and total hydrocarbon levels will be measured at the monitoring points before air injection. Normally, air will be injected into the ground for at least 20 hours at rates ranging from 1.0 to 1.7 cfm (60 to 100 cfh). Blowers to be used will be diaphragm compressors Model 4Z024 from Grainger (or equivalent) with a nominal capacity of 1.7 cfm (100 cfh) at 10 psi. The helium used as a tracer will be 99% or greater purity, which is available from most welding supply stores. The flow rate of helium will be adjusted to 0.6 to 1.0 cfh to obtain about 1% in the final air mixture which will be injected into the contaminated area. Helium in the soil gas will be measured with a Marks Helium Detector Model 9821 (or equivalent) with a minimum sensitivity of 0.01%.

After air and helium injection is completed, the soil gas will be measured for O_2, CO_2, helium, and total hydrocarbon. Soil gas will be extracted from the contaminated area with a soil gas sampling pump system similar to that shown in Figure 5-1. Typically, measurement of the soil gas will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours, depending on the rate at which the oxygen is utilized. If oxygen uptake is rapid, more frequent monitoring will be required. If it is slower, less frequent readings will be acceptable.

At shallow monitoring points, there is a risk of pulling in atmospheric air in the process of purging and sampling. Excessive purging and sampling may result in erroneous readings. There is no benefit in over sampling, and when sampling shallow points, care will be taken to minimize the volume of air extraction. In these cases, a low-flow extraction pump of about 0.03 to 0.07 cfm (2.0 to 4.0 cfh) will be used. Field judgment will be required at each site in determining the sampling frequency. Table 5-1 provides a summary of the various parameters which will be measured and their frequency.

The in situ respiration test will be terminated when the oxygen level is about 5%, or after 5 days of sampling. The temperature of the soil before air injection and after the in situ respiration test will be recorded.

5.7.2 Data Interpretation

Data from the in situ respiration and air permeability tests will be summarized, and their O_2 utilization rates, air permeability, and R_I will be computed. Further details on data interpretation are presented in Sections 5.7.2.1 and 5.7.2.2.

5.7.2.1 Oxygen Utilization

Oxygen utilization rates will be determined from the data obtained during the bioventing tests. The rates will be calculated as the percent change in O_2 over time. Table 5-2 contains the two sets of sample data which are illustrated in Figure 5-2. The O_2 utilization rate is determined as the slope of the O_2% vs. time line. A zero-order respiration rate as seen in the Fallon NAS data is typical of most sites; however, a fairly rapid change in oxygen levels may be seen as in the data from Kenai, Alaska. In the later, the oxygen utilization rate was obtained from the initial linear portion of the respiration curve.

To estimate biodegradation rates of hydrocarbon from the oxygen utilization rates, a stoichiometric relationship for the oxidation of the hydrocarbon will be used. Hexane will be used as the representative hydrocarbon, and the stoichiometric relationship used to determine degradation rates will be:

$$C_6H_{14} + 9.5\ O_2 \rightarrow 6CO_2 + 7H_2O$$

Based on the utilization rates (change of oxygen [%] per day), the biodegradation rate in terms of mg of hexane-equivalent per kg of soil per day will be estimated using the following equation.

$$K_B = -K_o\ A\ D_o\ C/100 \qquad (1)$$

where:

K_B = biodegradation rate (mg/kg day)
K_o = oxygen utilization rate (percent per day)

TABLE 5-1. Parameters to be Measured for the In Situ Respiration Tests

Parameter/Media	Suggested Method	Suggested Frequency	Instrument Sensitivity (Accuracy)
Carbon dioxide/soil gas	Infrared adsorption method, GasTech Model 32520X (0 to 5% and 0 to 25% carbon dioxide)	Initial soil gas sample before pumping air, immediately after pump shut off, every 2 hours for the first 8 hours, and then every 8 to 10 hours	±0.2%
Oxygen/soil gas	Electrochemical cell method, GasTech Model 32520X (0 to 21% oxygen)	Same as above	±0.5%
Total hydrocarbons (THC)/soil gas	GasTech hydrocarbon detector or similar field instrumentation	Initial soil gas sample before pumping air, then same as above if practical	±1 ppm
Helium	Marks Helium Detector Model 9821 or equivalent	Same as for carbon dioxide	±0.01%
Pressure	Pressure gauge (0 to 30 psia)	During air injection	0.5 psia
Flow rate/air	Flowmeter	Reading taken during air injection	±5 cfh

A $=$ volume of air/kg of soil (l/kg)
D_o $=$ density of oxygen gas (mg/l)
C $=$ mass ratio of hydrocarbon to oxygen required for mineralization.

Using several assumptions, values for A, D_o, and C can be calculated and substituted into equation 1. Assumptions used for these calculations are:

- Porosity of 0.3 (the air-filled porosity, which can range from 0.0 to 0.6 depending on the site soils and varies with moisture content in any given soil)

- Soil bulk density of 1,440 kg/m^3

TABLE 5-2. Sample Data Set for Two In Situ Respiration Tests

Fallon NAS, Nevada (Test Well A2)			Kenai, Alaska (Test Well K1)			
Time (Hours)	O_2(%)	CO_2(%)	Time (Hours)	O_2(%)	CO_2(%)	Helium
-23.5	0.05	20.4	-22.0	3.0	17.5	—
0	20.9	0.05	0	20.9	0.05	1.8
2.5	20.3	0.08	7.0	11.0	2.7	1.4
5.25	19.8	0.10	12.25	4.8	4.6	1.4
8.75	18.7	0.13	19.50	3.5	6.0	1.3
13.25	18.1	0.16	26.25	1.8	6.5	1.0
22.75	15.3	0.14	46.00	2.0	7.0	0.9
27.0	15.2	0.22				
32.5	13.8	0.14				
37.0	12.9	0.23				
46.0	11.2	0.22				
49.5	10.6	0.16				

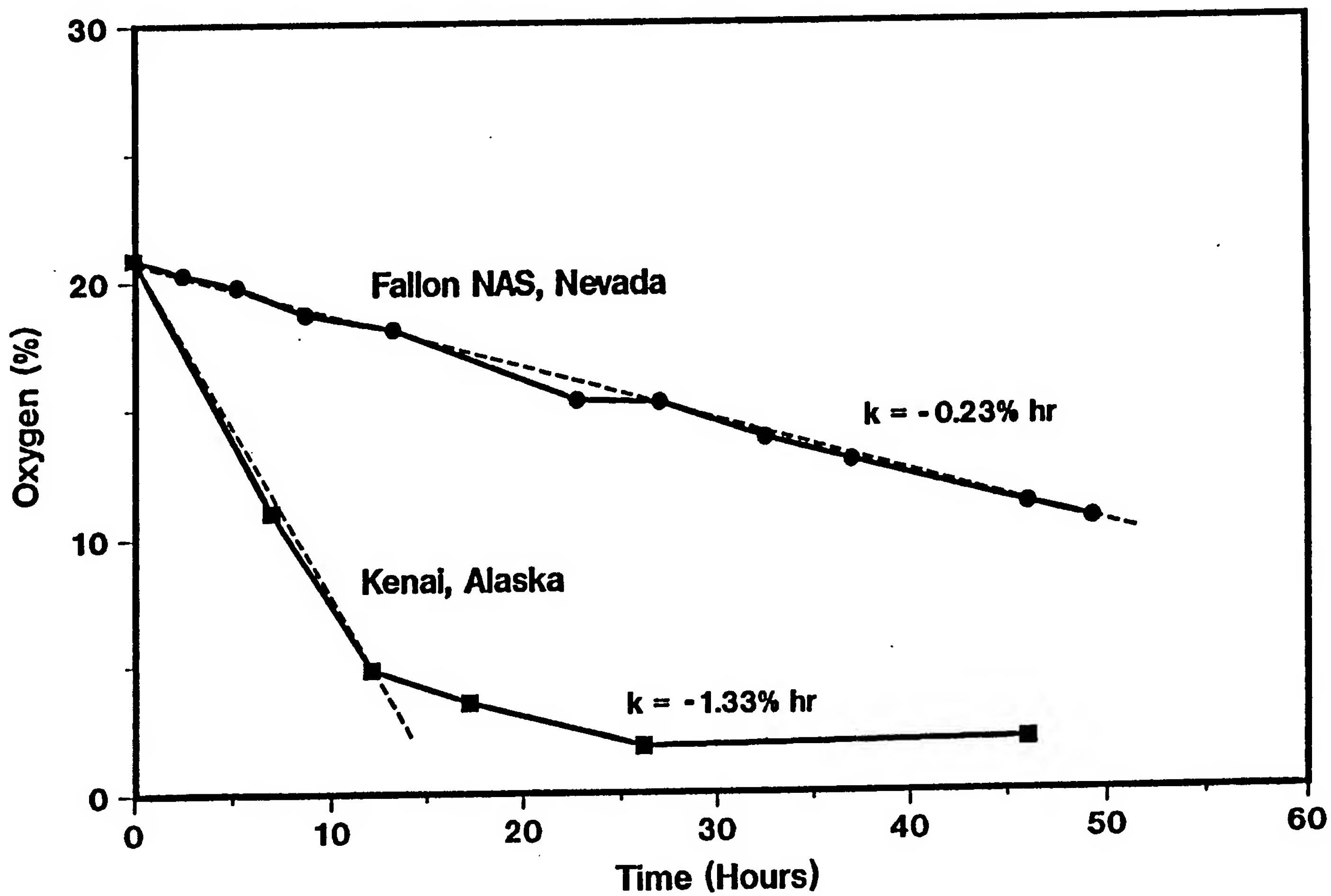

Figure 5-2. In Situ Respiration Test Results for Two Bioventing Test Sites: Fallon NAS, Nevada (Monitoring Point A2) and Kenai, Alaska (Monitoring Point K1).

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- D_o oxygen density of 1,330 mg/l (varies with temperature, altitude, and atmospheric pressure)

- C, hydrocarbon-to-oxygen ratio of 1/3.5 from the above equation for hexane.

Based on the above assumed porosity and bulk density, the term A, volume of air/mg of soil, becomes 300/1,440 = 0.21. The resulting equation is:

$$K_B = -(K_o)(0.21)(1330)(1/3.5)/100 = 0.8\ K_o \tag{2}$$

This conversion factor, 0.8, was used by Hinchee et al. (1991b) in their calculations of biodegradation rates of hydrocarbons. Another way to estimate biodegradation rates is based on CO_2 generation rates, but as discussed in Section 2.3, this is less reliable than using O_2 utilization rates.

5.7.2.2 Helium Monitoring

Figures 5-3 and 5-4 show typical helium data for two test wells. The helium concentration at monitoring point S1 (Figure 5-3) at Tinker AFB started at 1.5% and after 108 hours had dropped to 1.1%, i.e., a fractional loss of ~0.25. In contrast, for Kenai K3 (Figure 5-4), the change in helium was rapid (a fractional drop of about 0.8 in 7 hours), indicating that there was possible short-circuiting at this monitoring point. This suggested that the data from this monitoring point were unreliable, and so the data were not used in calculating degradation rates.

As a rough estimate, diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on the molecular weights of 4 and 32 g mol for helium and oxygen, respectively, helium diffuses about 2.8 times faster than oxygen. This translates into a fractional oxygen loss of ~0.095 for S1 of Tinker AFB, a minimal loss. The data from this monitoring point were used in the calculation rates. As a guide, data from tests where fractional helium loss is 0.4 or less over 100 hours, or an equivalent fractional oxygen loss of 0.15, are acceptable.

5.8 Bioventing Test

The bioventing test is the third and final part of the field treatability study and will consist of a longer term (6 months or more) air injection or withdrawal procedure. A blower will be installed immediately following completion of the air permeability and in situ respiration tests, and will be started before the field crew leaves the site. At some sites where regulatory approval is pending, the bioventing blower will be installed and started at a later date.

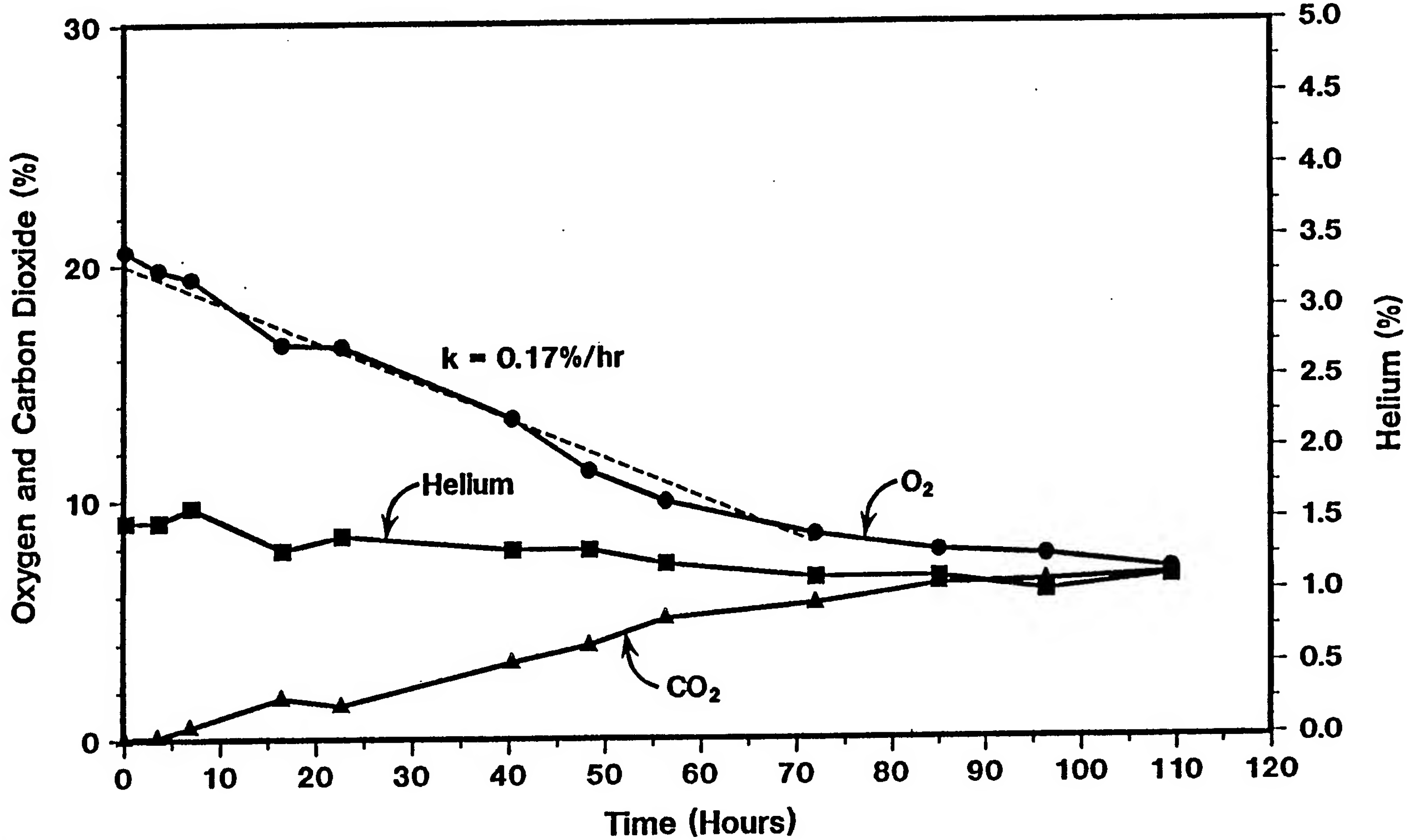

Figure 5-3. In Situ Respiration Test Results for Monitoring Point S1, Tinker AFB, Oklahoma.

KA/Org/5-03

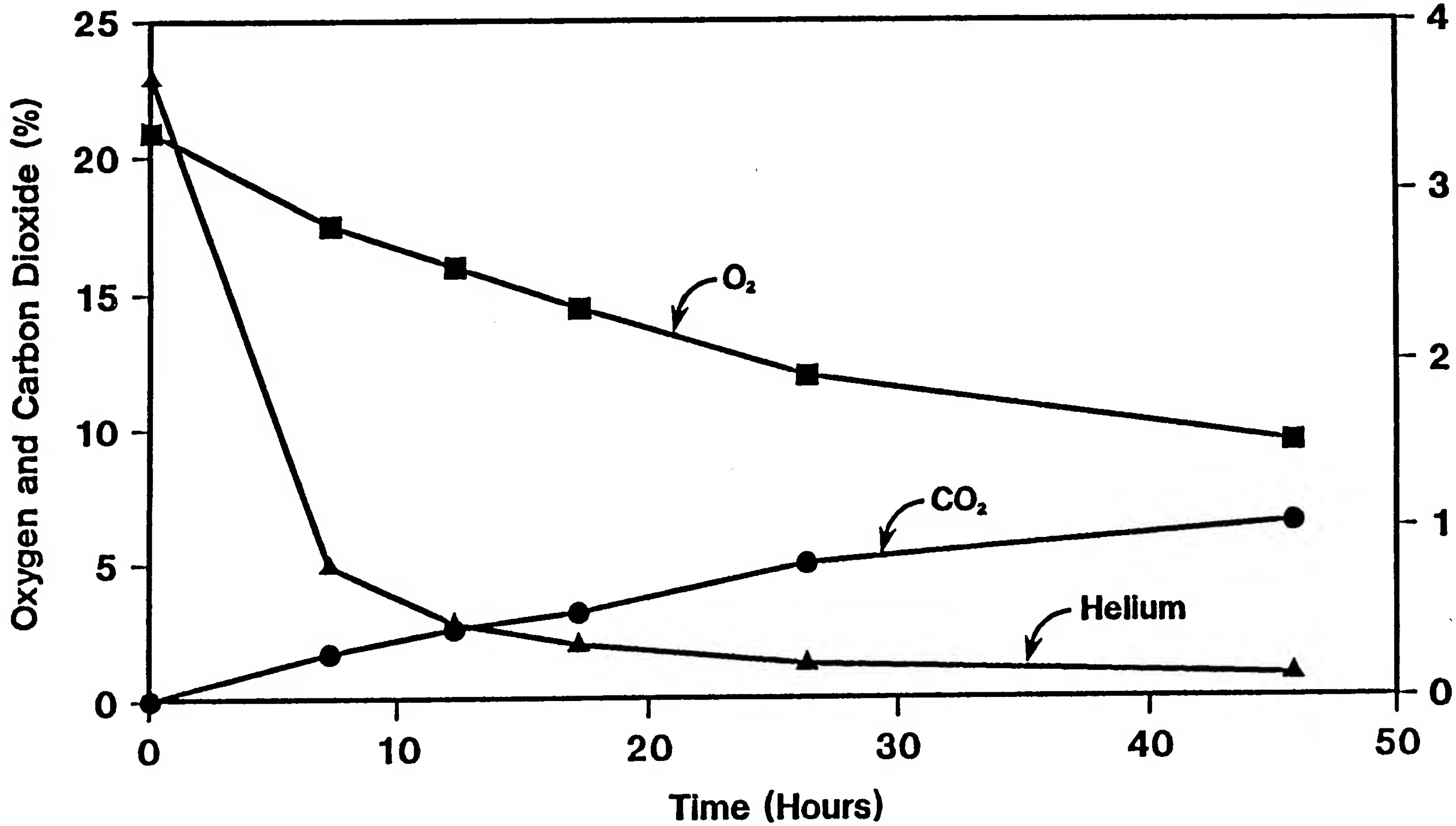

Figure 5-4. In Situ Respiration Test Results for Monitoring Point K3, Kenai, Alaska.

RA\Org\5-08

5.8.1 Criteria for Conducting the Bioventing Test

The contractor will plan on conducting the bioventing test at each site; however, at some sites the bioventing test may not be appropriate (e.g., where no bioremediation is stimulated). Upon completion of the soil gas permeability and the in situ respiration tests, the data will be analyzed and a decision will be made as to whether the bioventing test is to be implemented. This decision will be confirmed before the field crew leaves the site.

5.8.1.1 Air Permeability and Radius of Influence

The technology of soil venting has not advanced far enough to provide firm quantitative criteria for determining the applicability of venting based solely on values of k or R_I. In general, k must be sufficiently high to allow movement of oxygen in a reasonable time frame (1 or 2 days) from either the vent well, in the case of injection, or the atmosphere or uncontaminated soils, in the case of extraction. If such a flow rate cannot be achieved, O_2 cannot be supplied at a rate to match its demand.

The estimated radius of influence (R_I) is actually an estimate of the radius in which measurable soil gas pressures are affected and does not always equate to gas flow. In highly permeable gravel, for example, significant gas flow can occur well beyond the measurable radius of influence. On the other hand, in a low-permeability clay a small pressure gradient may not result in significant gas flow. In this study, the assumption will be made that the R_I does equate to the area of significant gas flow; however, care must be taken in applying this assumption. During air permeability testing, an increase in O_2 concentration within the monitoring points is often an additional indicator of R_I.

In general, if the R_I is greater than the depth of the vent well, the site is probably suitable for bioventing. If the R_I is less than the vent well depth, the question of practicality arises. To scale up a bioventing project at such a site may require more closely spaced vent wells than is either economically feasible or physically possible. The decision to proceed with bioventing will be site-specific and somewhat subjective.

5.8.1.2 Biodegradation Rate

The decision to proceed with the bioventing will be based on the results of the degradation rate calculations. From previous studies, the oxygen utilization rates that can be expected from sites contaminated with jet fuel are between 0.05 to 1.0% O_2/hour. If rates within this range are obtained and are significantly greater than background, there is sufficient evidence to assume that some microbial activity is occurring and that the addition of O_2 in these contaminated areas will enhance biodegradation. If soil gas O_2 levels are above 2 to 5% prior to any air injection, or if oxygen utilization rates are not greater than background, venting will most probably not stimulate biodegradation and consideration will be given to terminate the bioventing effort.

5.8.1.3 Regulatory Approval

Regulatory approval requirements will be defined, and if necessary, approvals will be obtained prior to initiating the bioventing test procedures. If approval is pending, a blower will be installed for startup at a later date. This will reduce costs by eliminating the need for a second visit.

5.8.1.4 U.S. Air Force Approval

Both the project officer and the base POC will be notified either verbally or in writing of the plans for initiating the bioventing test, and their approval will be required before the test is initiated. Verbal approval will be documented by the contractor.

5.8.2 Air Injection vs. Extraction Considerations

Air injection will be used as the method of choice to provide oxygen for the initial and extended pilot tests. Air injection does not result in a direct discharge of volatile organics to the atmosphere and is less expensive to operate and maintain than extraction systems. Air injection systems produce no condensate, no liquid wastes, and no contaminated air stream, and they usually do not require air permitting. Under some circumstances the use of soil gas extraction systems will need to be incorporated into the air injection system design. For example, whenever the radius of pressure influence (> 0.1" H_2O) of a vent well is close to basements or occupied surface structures, an air extraction system will be used to reduce the risk of moving gases into these areas. This precaution will prevent the accumulation of explosive or toxic vapors in these structures.

When necessary, soil gas will be extracted away from these structures and then reinjected in a unsaturated zone well on the opposite side of the extraction well. If necessary, makeup air will be added prior to reinjection to maintain oxygen levels sufficient for biodegradation (see Figure 2-3). This configuration will also have the advantage of producing no direct discharge of volatile organics to the atmosphere, as the volatiles will be returned to the contaminated zone for treatment by the soil's active biomass.

5.8.3 Blower System Installation

On sites where initial pilot testing is successful, and the criteria in Section 5.8.1 are met, a blower system will be installed for the extended bioventing test. The blower will be configured and instrumented as shown in Figure 4-3 or 4-4. This instrumentation will ensure that important flow rate, temperature, and pressure data can be collected by base personnel during extended testing. The blower will be sized to provide a soil gas flow that is sufficient to influence all monitoring points within the contaminated zone and to provide oxygen at a rate that exceeds the highest oxygen utilization rate measured during initial testing.

Whenever possible, the blower will be sized to use the existing power source at or near the site. All electrical connections and disconnect devices will conform to local and base electrical codes. An explosion-proof blower and motor will be required for all extraction systems and in all fuel storage areas where explosion-proof equipment is mandatory. After coordination with base officials, the blower will be sited and placed in a secure and unobtrusive place. The blower will be placed in a small, portable protective shelter that is painted to conform to base color schemes. This enclosure will seldom exceed a 3-ft x 4-ft footprint and a height of 4 ft. The enclosure will protect the motor and blower from the weather and must be adequately ventilated to prevent the motor from overheating during summer months.

If necessary in high-traffic areas, piping from the vent well to the blower will be buried several inches below the surface to prevent damage. The blower system, monitoring points, and piping will be installed so as to minimize interference with existing site activities.

5.8.4 Blower Operation and Maintenance

If the site is selected for extended testing, base personnel will be required to perform a simple weekly system check to ensure that the blower is operating within its intended flow rate, pressure, and temperature range. This check must be coordinated with the base POC. Prior to departing the site, the contractor will provide a 1-hour on-site briefing for base personnel who will be responsible for blower system checks. The principle of operation will be explained, and a simple checklist and logbook will be provided for blower data. Bioventing systems are very simple, with minimal mechanical and electrical parts. Minor maintenance such as replacing filters or gauges, or draining condensate from knockout chambers, will be performed by base personnel, but they will not be expected to perform complicated repairs or analyze gas samples. Replacement filters and gauges will be provided and shipped to the base by the contractor. Serious problems such as motor or blower failures will be corrected by the contractor.

5.8.5 Long-Term Monitoring

Most bioventing systems will require 2 or 3 years of operation to significantly reduce soil hydrocarbon levels. The progress of this system will be monitored by conducting semiannual respiration tests in the vent well and in each monitoring point, and by regularly measuring the O_2, CO_2, and hydrocarbon concentrations in the extracted soil gas and comparing them to background levels. If air injection is used, the blower can be temporarily reversed and the extracted soil gas monitored for O_2, CO_2, and hydrocarbons. Soil gas monitoring will be performed by specialized Air Force or contractor personnel on a quarterly basis. Semiannual respiration tests will be performed by the Air Force or by contractor personnel. At least twice each year, the progress of the bioventing test will be reported to the base POC.

6.0 SCHEDULE

The expected schedule for the on-site air permeability, in situ respiration, and bioventing tests is dependent on the depth to groundwater, as follows:

Case I — (Shallow Groundwater, ~20 ft or less)	Day After Initiation
— Review available data and develop plan	0-5[a]
— Air Force review	8-12
— Soil gas survey	13-15
— Install vent well/monitoring points	16-18
— Soil permeability test	19
— In situ respiration test	20-24
— Install blower and start up bioventing system	24-26
Case II — (Deep Groundwater, ~20 ft or more)	
— Review available data and develop plan	0-5[a]
— Air Force review	8-12
— Exploratory borings	13-15
— Install vent well/monitoring points	16-19
— Soil permeability test	20
— In situ respiration test	21-25
— Install blower and start up bioventing system[b,c]	26-27
Case I and II — Bioventing Test	**Month After Initiation**
— Determine regulatory requirements[b] (if any)	0
— Install and start[c] blower	1
— Conduct on-site testing	Every 6 months

(a) It will be necessary to begin the process of permitting and contracting with drillers as soon as possible after contract award, and this must be nearly complete by day 0.

(b) Regulatory requirements will need to be investigated and any required permitting or approvals initiated as soon as possible after a site is identified as a potential candidate. It is assumed in this schedule that any required permits or approvals will have been obtained prior to starting.

(c) The blower will be started only after any required regulatory approvals are received, and with the concurrence of the base POC and project officer.

These schedules are based on the assumptions that (1) no special problems will be encountered; (2) the sites will be easily accessible; and (3) useable vent well and monitoring point locations will be quickly identified. Any problems or deviations will result in a longer time frame. Deeper drilling requirements will extend the testing schedule.

7.0 REPORTING

The section describes the reports to be generated. For consistency, the following units will be used:

— English measurements for length, volume, flow, pressure, and mass, specifically:

- feet and inches for length
- gallons and ft^3 for volume
- cfh and cfm for flow
- psig for pressure
- lb for mass

— Metric units for concentrations, rates, and temperature, specifically:

- mg/l for aqueous concentrations
- mg/kg for soil concentrations
- mg/(kg day) for hydrocarbon degradation
- °C for temperature

— Gaseous concentrations and O_2 utilization rates as follows:

- ppm for hydrocarbons (parts per million, i.e., µl/l, by volume)
- percent (%) for O_2, CO_2, and He (percent by volume, i.e., l x 100%/l)
- %/hr for O_2 utilization

To avoid confusion when discussing gases, the term percent (%) will refer only to concentration. Relative changes will be expressed as fractions. For example, if the O_2 concentration changes from 20% to 15%, the change will be referred to as a 5% reduction or a fractional reduction of 0.25, *not* a 25% reduction.

7.1 Test Plan

A Test Plan for each site will be prepared and submitted to the project officer and the base POC for approval. The Test Plan will consist of this generic Test Plan which provides the scope and planned activities, and a cover letter describing site-specific applications. The Test Plan will be submitted to the project officer and base POC as early as possible before the start of the on-site test.

7.2 Monthly Reports

The contractor will provide a written monthly progress report to the project officer outlining the work accomplished for the month, the problems encountered, approaches to overcome the problems, and anticipated progress for the following month. Included in this report will be the monthly expenditure and the accumulated expenditure to date.

7.3 Verbal Communication

The contractor will be in communication with the project officer and the base POC and will report on field activities and associated problems. Oral reports will be made either to the project officer or base POC, upon demand and at least weekly to the project officer.

7.4 Site Reports

The contractor will provide a letter report (normally less than 15 pages) for each site describing the results of the soil gas permeability and in situ respiration tests as well as a description of the bioventing test initiated. This report will normally be submitted to the project officer, base POC, and others as directed by the project officer 60 days after completion of the treatability test.

8.0 RECORD OF DATA AND QUALITY ASSURANCE

A project record book will be maintained during the field tests to record events pertaining to site activities, including sampling, changes in process conditions (flow, temperature, and pressure), equipment failure, location of the test wells, calibration, and data for the respiration/air permeability tests and long-term bioventing test. The record book will be reviewed by the contractor's project manager. The project officer may review the record book upon request. Typical record sheets for the respiration and air permeability tests are shown in Figure 8-1 and 8-2, respectively. Figure 8-3 shows a typical record sheet for the long-term bioventing test.

Quality assurance will be implemented throughout the project through quality planning, quality control and quality assessment. This will include daily calibration of field analytical instrument with purchased calibration standards prior to use. Field blanks will consist of ambient air drawn through the entire sampling train set-up in an uncontaminated area of the field site. Quality assurance activities include a review of all field activities and procedures by the project manager to ensure compliance with this protocol and quality guidelines. Monthly reports to the project officer will include any significant quality assurance problems and recommended solutions.

Figure 8-1. Typical Record Sheet for In Situ Respiration Test.

SITE ______________________ MONITORING POINTS ______________________

DATE ______________________ O_2 METER NO. ____________ CO_2 METER NO. ____________

LOCATION ______________________ HYDROCARBON METER NO. ______________________

SAMPLER(S) ______________________ SHUT DOWN DATE ____________ TIME ____________

Date/ Time	CO_2%	O_2%	Total Hydrocarbon	Helium	Comments	Date/ Time	CO_2%	O_2%	Total Hydrocarbon	Helium	Comments

Figure 8-2. Typical Record Sheet for Air Permeability Test.

SITE ______________________ TYPE OF TEST ______________________

DATE ______________________ TEST DATE ______________________

SAMPLER(S) ______________________ TIME ______________________

Pressure/Vacuum ("H_2O)

Distance from Vent Well (ft)						Distance from Vent Well					
Time	ln(t)	MP1	MP2	MP3	MP4	Time	ln(t)	MP5	MP6	MP7	MP8

Figure 8-3. Typical Record Sheet for Long-Term Bioventing Test.

SITE ____________________ MONITORING POINTS ____________________

DATE ____________________ O_2 METER NO. __________ CO_2 METER NO. __________

LOCATION ____________________ HYDROCARBON METER NO. ____________________

SAMPLER(S) ____________________ SHUT DOWN DATE __________ TIME __________

Date/ Time	CO_2%	O_2%	Total Hydrocarbon	Air Flow Rate (cfm)	Comments	Date/ Time	CO_2%	O_2%	Total Hydrocarbon	Air Flow Rate (cfm)	Comments

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APPENDIX

RECOMMENDED ESTIMATION METHODS FOR AIR PERMEABILITY

The U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory recently reviewed several field, laboratory, and empirical methods for determining soil gas permeability (k) and for their appropriateness in determining the feasibility of soil vapor extraction (Sellers and Fan, 1991). The conclusion of this literature review was a strong endorsement for a modified field drawdown method (Johnson et al., 1990).

The field drawdown method is based on Darcy's Law and equations for steady-state radial flow to or from a vent well. A full mathematical development of this method and supporting calculations are provided by Johnson et al. (1990). A computer program known as HyperVentilate™ has been produced by Johnson for storing field data and computing k and R_I. This program will be used to speed the calculation and data presentation process. The two solution methods for k are presented below. The first solution is based on carefully measuring the dynamic response of the soil to a constant injection or extraction rate. The second solution for k is based on steady-state conditions and the measurement or estimation of R_I at steady state. The limitations and recommended application of each method are presented below. Whenever possible, field data will be collected to support both solution methods, because one or both of the solution methods may be appropriate, depending on site-specific conditions.

Dynamic Method

This test method requires that air be extracted or injected at a constant rate from a single venting well, while measuring the pressure changes at several soil gas monitoring points throughout the contaminated soil volume. The equation:

$$P' = \frac{Q}{4\pi\, m(k/\mu)} \left[-0.5772 - \ln \frac{(r^2 e\mu)}{4k\, Patm} + \ln(t)\right] \tag{1}$$

is used to describe the dynamic changes in soil gas pressure/vacuum where:

- P' = "gauge" pressure measured at distance r from the vent well at time t(g/cm-s^2)
- m = stratum thickness, generally the vent well screened interval (cm)
- r = radial distance from monitoring point to vent well (cm)
- k = soil gas permeability (cm^2)
- μ = viscosity of air (1.8×10^{-4} g/cm-s at 18°C)
- e = soil's air-filled void volume (dimensionless)
- t = time from the start of the test (s)
- Q = volumetric flow rate from the vent well (cm^3/s)
- Patm = ambient pressure (at sea level 1.013×10^6 g/cm-s^2)

Equation (1) predicts that the dynamic range of P′-vs.-ln(t) is a straight line with a slope of A where:

$$A = \frac{Q}{4\pi m\ (k/\mu)}$$

solving

$$k = \frac{Q\mu}{4A\pi m}$$

The HyperVentilate™ model is based on the dynamic method and a determination of the slope, A. This method of determining k requires accurate field measurements of Q at the vent well and P′s-vs.-time at each monitoring point. It is most appropriately applied at sites with less permeable soils where changes in P′ occur over a longer time period (10 minutes or more to monitoring point steady state). This method can be accurate for fine sandy soils where the screened interval extends to depths of over 10 ft and when monitoring points are screened at depths of 10 ft or greater. It is less accurate for sites where a high water table or shallow contamination limits the total depth of the vent well screen and monitoring points to less than 10 ft. In shallow and coarse-grained soils, vacuum or pressure levels reach steady state too rapidly to accurately plot P′-vs.-ln(t). Venting systems on shallow sandy sites are subject to higher vertical airflow which is not as accurately described by this one-dimensional radial flow equation.

Steady State-Method

This method for determining k can be used in situations where the dynamic method is inappropriate. This method is based on the steady-state solution to equation (1).

$$k = \frac{Q\mu \ln(Rw/R_I)}{H\pi\ Pw\ [1 - (Patm/Pw)^2]} \qquad (2)$$

Note: Equation (2) applies only to vent wells operating under a vacuum. If air is being injected into the vent well the equation is modified as shown below:

$$k = \frac{Q\mu \ln(Rw/R_I)}{H\pi\ Patm\ [1 - (Pw/Patm)^2]} \qquad (3)$$

where Q, m, μ, and Patm have been previously defined, and

Rw = the radius of the venting well (cm)

H = depth of screen (cm)

R_I = the maximum radius of venting influence at steady state (cm)

Pw = the absolute pressure at the venting well ($g/cm\text{-}s^2$)

The value of R_I can be determined by actually measuring the outer limit of vacuum/pressure influence under steady-state conditions, or by plotting the vacuum/pressure at each monitoring point vs. the log of its radial distance from the vent well and extrapolating the straight line to zero vacuum or pressure. An example of this solution method is included in Calculation Data Set Two below.

Sample Calculations

Data Set One

Table A-1 and Figure A-1 present the results of an air permeability test conducted at Beale AFB, CA. The soils on this site were silty with a contaminated interval (and vent well screen interval) extending from 10 to 40 feet below ground surface. Note that the plot of P′-vs.-ln(time) is a relatively straight line during the initial 10 minutes, ln (10) = 2.3, making these data good candidates for the dynamic solution method. Data from the initial 10 minutes of this test were entered into the Hyper-Ventilate™ computer model to calculate a range of k values. An example of the input and output data for this model is provided in windows AP7 and AP8.

HyperVentilate© 1991

Air Permeability Test - Data Analysis (cont.)

The permeability, k, can then be calculated by one of two methods:

1. The first is applicable when both Q (flowrate) and m (well screen interval) are known accurately. The calculated slope A is used:

$$k = \frac{Q\,\mu}{4\,A\,\pi\,m}$$

2. The second approach is used whenever Q or m are not known with confidence. In this case, both the slope, A, and intercept, B, are used:

$$k = \frac{r^2\,\varepsilon\,\mu}{4\,P_{Atm}} \exp[\,0.5772 + \frac{B}{A})]$$

Return AP7

Air Permeability Test - Data Analysis (cont.)

(1) Enter radial distances of monitoring points → r= 40 (ft) | r= 20 (ft) | r= 10 (ft)

(2) Enter measured times and gauge vacuums →

(3) Enter (optional):

a) flowrate 51 (SCFM)

b) screened interval thickness 30 (ft)

r=40 (min)	(in H2O)	r=20 (min)	(in H2O)	r=10 (min)	(in H2O)
.5	0.1	.5	.4	.5	1.5
1	0.21	1	1.4	1	4.5
1.5	0.62	1.5	2.8	1.5	7.5
2	1.00	2	3.6	2	9
2.5	1.25	2.5	4	2.5	10
3	1.41	3	4.4	3	10.7
3.5	1.60	3.5	5	3.5	11.2
4	1.8	4	5.3	4	11.8
4.5	1.98	4.5	5.6	4.5	12
5	2.12	5	5.8	5	12.4

clear | clear | clear

-->Calculate<--

	r=40	r=20	r=10
k= darcy (A)	14.2021	6.75944	4.00444
k= darcy (B)	84.6266	34.6443	15.9240

Return | Explanation & Statistics | AP8

Air Permeability Test - Data Analysis (cont.)

(1) Enter radial distances of monitoring points → r= 40 (ft) | r= 20 (ft) | r= 10 (ft)

(2) Enter measured times and gauge vacuums →

(3) Enter (optional):

a) flowrate 51 (SCFM)

b) screened interval thickness 30 (ft)

r=40 (min)	(in H2O)	r=20 (min)	(in H2O)	r=10 (min)	(in H2O)
5.5	2.25	5.5	6	5.5	12.5
6	2.37	6	6.1	6	12.6
6.5	2.48	6.5	6.2	6.5	12.6
7	2.55	7	6.3	7	12.7
7.5	2.63	7.5	6.4	7.5	12.7
8.5	2.82	8.5	6.5	8.5	12.4
9.5	2.92	9.5	6.5	9.5	12.5

clear | clear | clear

-->Calculate<--

	r=40	r=20	r=10
k= darcy (A)	14.2021	6.75944	4.00444
k= darcy (B)	84.6266	34.6443	15.9240

Return | Explanation & Statistics | AP8

TABLE A-1. Air Permeability Data Set

Steady–State Flow Rate 51 SCFM

Test Time Elapsed (min)	In Time (min)	Vacuum (inches of water) at Monitoring Points (MPs) MP 1	MP 2	MP 3	MP 4	MP 5	MP 6	MP 7	MP 8	MP 9	
0.0	–	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.5	–	–	–	–	–	–	–	0.10	0.40	1.50	
1.0	0.00	–	–	–	–	–	–	0.21	1.40	4.50	
1.5	0.41	–	–	–	–	–	–	0.62	2.80	7.50	
2.0	0.69	–	–	–	–	–	–	1.00	3.60	9.00	
2.5	0.92	–	–	–	–	–	–	1.25	4.00	10.00	
3.0	1.10	–	–	–	–	–	–	1.41	4.40	10.70	
3.5	1.25	–	–	–	–	–	–	1.60	5.00	11.20	
4.0	1.39	–	–	–	–	–	–	1.80	5.30	11.80	
4.5	1.50	–	–	–	–	–	–	1.98	5.60	12.00	
5.0	1.61	–	–	–	–	–	–	2.12	5.80	12.40	
5.5	1.70	–	–	–	–	–	–	2.25	6.00	12.50	
6.0	1.79	–	–	–	–	–	–	2.37	6.10	12.60	
6.5	1.87	–	–	–	–	–	–	2.48	6.20	12.60	
7.0	1.95	–	–	–	–	–	–	2.55	6.30	12.70	
7.5	2.01	–	–	–	–	–	–	2.63	6.40	12.70	
8.5	2.14	–	–	–	–	–	–	2.82	6.50	12.40	
9.5	2.25	–	–	–	–	–	–	2.92	6.50	12.50	
10.5	2.35	–	–	–	–	–	–	2.96	6.50	12.50	
14.0	2.64	–	–	–	–	–	–	3.00	6.50	12.40	
19.0	2.94	–	–	–	–	–	–	3.05	6.40	11.90	
24.0	3.18	–	–	–	–	–	–	3.10	6.20	11.00	
29.0	3.37	–	–	–	–	–	–	3.37	6.00	10.40	
34.0	3.53	–	–	–	–	–	–	3.40	5.80	9.90	
39.0	3.66	–	0.8	0.4	0.7	2.2	1.7	3.40	–	–	
44.0	3.78	0.3	–	–	–	–	–	–	–	–	
								40	20	10	<--- Distance from VE – 2
		27.5–29.5	18–20	13–15	14–16	38–40	30–32	38–40	38–40	38–40	<--- Screen interval depth

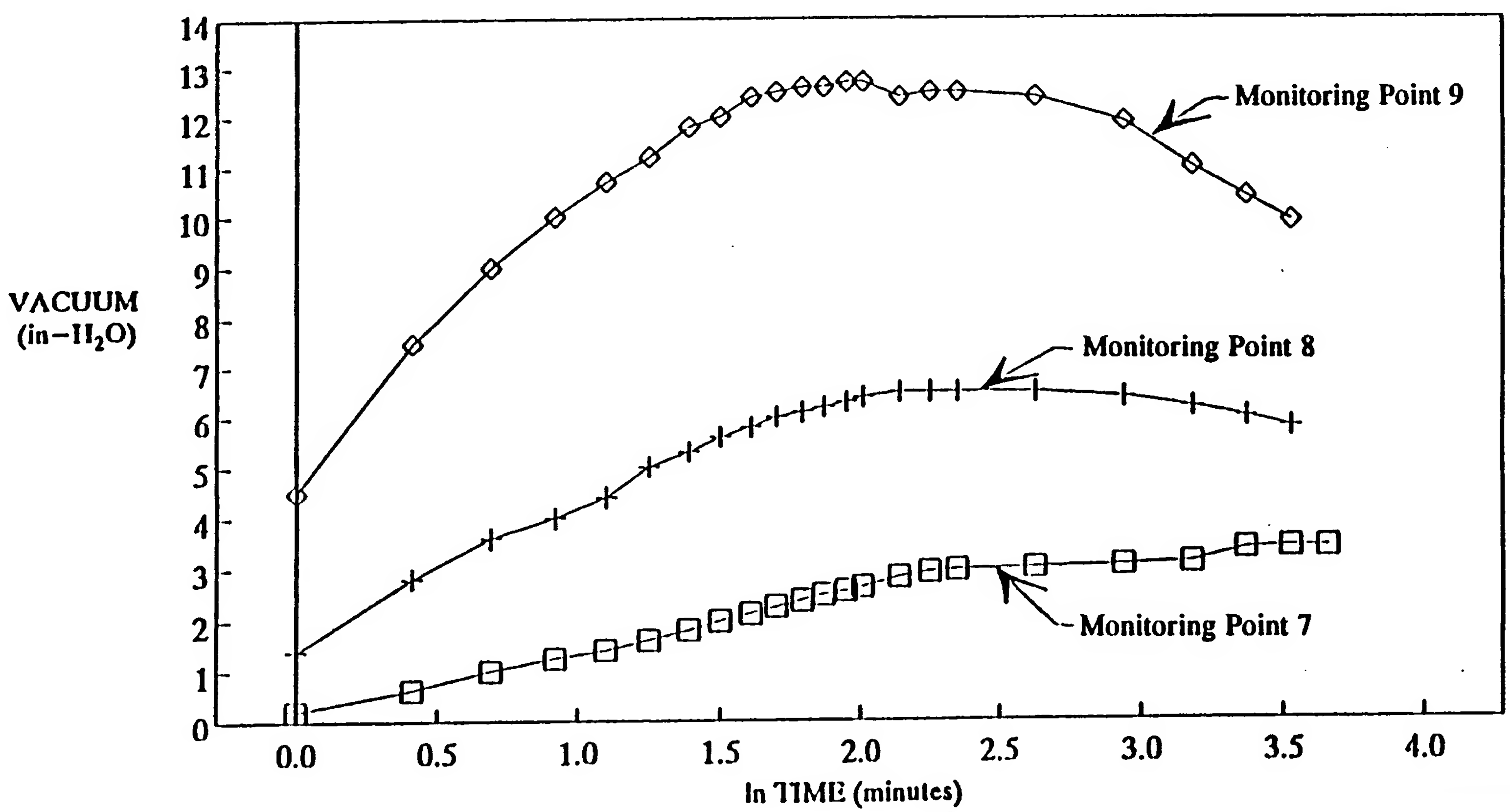

Figure A-1. Vacuum vs. ln Time, Test 2, Bioventing Pilot Test, Site 22-A20, Beale AFB, California

Computer window AP7 provides a summary of two mathematical solutions for air permeability (k) using the dynamic method. Window AP8 is the example data entry and solution sheet. The calculated range of k values for this test is shown at the bottom of window AP8. Permeability values of 4 to 14 darcy are based on Equation 1 in window AP7 and provide the most accurate estimate, because both the extraction rate (Q) and the screened interval (m) were known for this test. The more conservative range of 4 to 14 darcy will be used for full-scale design. These air permeability values are approximately one order of magnitude higher than would be expected for silty soils. The presence of 10 to 15% sand (by weight) in this soil has increased the average permeability at this site.

Data Set Two

Table A-2 and Figure A-2 are the results from a test conducted in a silty loam with a contaminated interval of only 5.2 ft and a screened interval from 2.7 to 5.2 ft below ground surface. Note that the almost immediate steady state reached at this site does not produce the P′-vs.-ln(time) plot required for the dynamic solution method. In this case the steady-state solution offers the only approximation of k and R_I.

$$k = \frac{Q\mu \ln(Rw/R_I)}{H\pi \, Pw \, [1 - (Patm/Pw)^2]}$$

For this test:

$Q = 1.4 \times 10^4 \text{ cm}^3/\text{s}$

$H = 2$ ft (61 cm)

$\mu = 1.8 \times 10^{-4}$ g/cm-s

$$Pw = 80\text{"}H_2O \text{ vacuum} \times 3.61 \times \frac{10^{-2} \text{ psia}}{\text{"}H_2O} = 2.88 \text{ psia}$$

Pw absolute = 14.7 psia – 2.88 psia = 11.82 psia

$$11.82 \text{ psia} \times 6.9 \times \frac{10^4 \text{g/cm-s}^2}{\text{psia}} = 8.16 \times 10^5 \text{g/cm-s}^2$$

$Patm = 1.01 \times 10^6 \text{g/cm-s}^2$

Rw = 1 in. = 2.54 cm

R_I = ~15 ft (457 cm) based on all monitoring points reported in Table A-2

TABLE A-2. Field Test Data for Soil Determination of Soil Permeability at a Gasoline-Contaminated Site

Time (min)	Air Flow (cfm)	Vacuum (inches of water) measured at various monitoring points										
		Unit	Well	F	E	G	D	H	C	I	B	A
0.0	0	0	2	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	30	109	80	1.90	0.90	0.25	0.15	0.00	0.00	0.00	0.00	0.00
1.5	30	109	80	1.90	0.90	0.30	0.20	0.05	0.00	0.00	0.00	0.00
5.0	30	109	80	1.90	0.90	0.30	0.20	0.05	0.00	0.00	0.00	0.00
10.0	30	109	80	1.90	0.95	0.30	0.20	0.05	0.00	0.00	0.00	0.00
15.0	30	109	80	1.90	0.95	0.30	0.20	0.05	0.00	0.00	0.00	0.00
20.0	30	109	80	1.90	0.95	0.30	0.20	0.05	0.00	0.00	0.00	0.00
		Distance from well (ft)		3	6	9	12	15	18	21	24	27

$Rw = 2.54$ cm $\mu = 1.8 \times 10^{-4}$ g/cm-s

$H = 60.96$ cm $Patm = 8.14 \times 10^{5}$ Dynes/cm^2

$Q = 14{,}158$ cm^3/sec

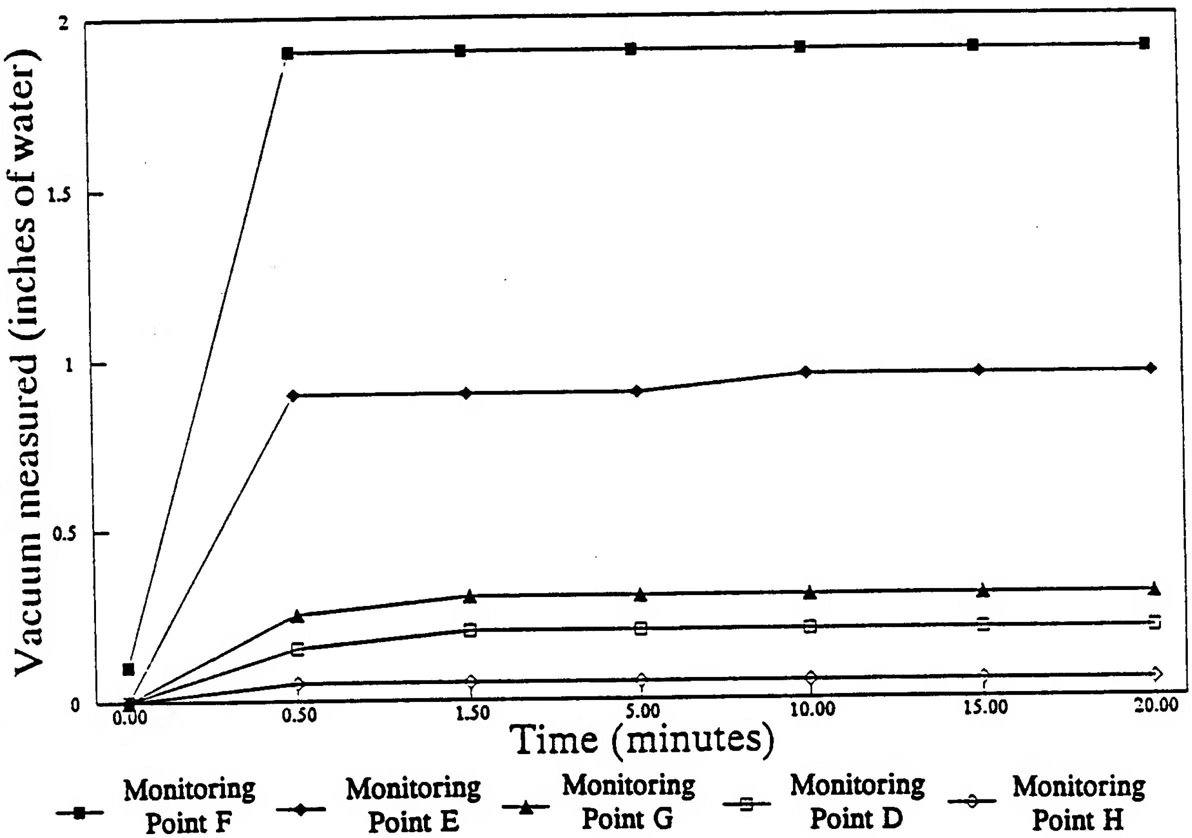

Figure A-2. Results of a Field Test to Determine Soil Permeability to Airflow, k, September 16, 1991

$$k = \frac{(1.4 \times 10^{4} \mathrm{cm^3/s})(1.8 \times 10^{-4} \mathrm{g/cm\text{-}s}) \ln(2.54/457)}{(61\ \mathrm{cm})(3.14)(8.16 \times 10^{5} \mathrm{g/cm\text{-}s})(1 - [1.01/0.816]^{2})}$$

$k = 1.6 \times 10^{-7}\ \mathrm{cm}^2$ or <u>0.16 darcy</u>, which is typical for silty soils.

References

Johnson, P.C., M.W. Kemblowski, and J.D. Colthart. 1990. "Quantitative Analysis for the Cleanup of Hydrocarbon-Contaminated Soils by In-Situ Soil Venting." *Ground Water* 28(3), May-June.

Sellers, K., and C.Y. Fan. 1991. "Soil Vapor Extraction: Air Permeability Testing and Estimation Methods." In: *Proceedings of the 17th RREL Hazardous Waste Research Symposium*. EPA/600/991/002, April.

APPENDIX D
ES ADDENDUM TO TECHNICAL PROTOCOL

ES ADDENDUM TO PROTOCOL DOCUMENT

INSERT 1. p. 27 Add to criteria 4

At sites that will have underground piping between the blower and vent well, the upper 18-inches of annular space will be left open to allow access for below-grade well head completion.

INSERT 2. p 31 Replace first three paragraphs

Monitoring point construction will vary depending on the depth of drilling, drilling technique, and soil and hydrologic conditions. Basically, the monitoring points will consist of rigid, 1/4-inch inside diameter, Schedule 80 PVC pipe to the specified depth with a 6-inch length of 1-inch diameter Schedule 40 PVC well screen with 0.020-inch slots. Each monitoring point screen will be centered within a 1 to 2 foot thick sand pack consisting of clean, rounded silica sand with a 6-9 sieve grain size. In low permeability soils, a slightly longer sand pack may be desirable. In wet soils, and where the depth to the groundwater surface fluctuates greatly, a longer sand pack with the screen near the top may be desirable. An approximately 1-foot thick sand pack will also be placed directly below the well box to provide drainage.

The annular space between sand packs will be filled with bentonite to form air-tight seals between sampling intervals. The bentonite seals will be hydrated in place instead of using bentonite slurry to assure long-term integrity of the seals. Bentonite slurry emplaced in monitoring points constructed in dry and/or sandy soils may dehydrate and shrink with time, resulting in the loss of the seal and settling or collapse of the overlying sand pack. The 2 feet of bentonite immediately above and below the annular sand pack intervals will consist of 1/4-inch diameter sodium bentonite pellets or granular bentonite less than 1/4-inch in diameter. These 2-foot thick intervals will be placed in 6-inch layers and each layer hydrated with potable water before placement of subsequent layers. To assure adequate hydration of each 6-inch bentonite layer, the water will be added in 2 or 3 portions with sufficient time allowed between additions to allow for hydration. The bentonite is sufficiently hydrated when the water will no longer penetrate the seal. Backfill between bentonite seals will consist of bentonite chips (hole plug) hydrated in place with potable water.

PVC pipe will be used to collect soil gas for CO_2 and O_2 analysis in the 0.25% range, and for JP-4 hydrocarbons in the 100 ppm range or higher. The pipe material must have sufficient strength and be nonreactive. Sorption and gas interaction with the pipe materials have not been significant problems for this application. If a monitoring point will be used to monitor specific organics in the low ppm or ppb range, Teflon\ or stainless steel may be necessary. However, this will not normally be the case.

The top of each ¼inch PVC pipe will be finished with a ¼inch ball valve fitted with a 3/16 inch hose barb. Each screened depth will be labeled using aluminum tags with a name as follows:

INSERT 3. p. 33, Section 4.2.4 Replace 3rd sentence

Type K (chromel-Alumel) thermocouples with Type K mini connectors will be used.

INSERT 4. p. 33 Replace Section 4.3

4.3 Background Monitoring Point

In addition to the vent well and the monitoring points installed in contaminated soils, a background monitoring point will be installed in uncontaminated soil to monitor the background respiration of natural organic matter. Soil gas in uncontaminated soil generally has O_2 levels between 15 and 20% and CO_2 levels between 1 and 5%. The background monitoring point will be similar in construction to the monitoring points installed in contaminated soils (Figure 4-2) and screened at similar depths in the same stratigraphic formation.

Alternatively, an existing groundwater monitoring well can be used as a background monitoring point if the well is installed in clean soils and the well screen extends several feet above the groundwater surface.

INSERT 5. p. 37 following 1st paragraph

WELL PURGING PROCEDURES

Prior to performing the following measurements and collecting soil gas samples, the vent well and monitoring point volumes must be purged. The purge volume should be approximately three times the vent well or monitoring point volume. Required purge volumes vary with length of sand pack, bore hole diameter and soil type. To determine adequate purging times for each sampling point, oxygen concentrations will be monitored during the initial purging until the concentrations reach a minimum value. Figure 5-1 shows a typical setup for the initial purging. For the vent well, this will depend on depth. For monitoring points and soil gas probes, this purging typically takes less than one minute using a one cubic foot per minute (cfm) pump. The required purge time will be recorded in the field book and used for all subsequent purging to ensure consistent measurements. Especially in fine-grained soils, it is important to avoid over-purging, which can draw in fresh, oxygenated air and result in erroneous measurements. Samples and measurements should be taken immediately upon completion of purging. NOTE: FOR ANYTHING OTHER THAN SANDY SOILS THE SAMPLE MUST BE COLLECTED USING THE VACUUM CHAMBER (EGG).

INSERT 6. p. 44 Replace title of Section 5.5

5.5 COLLECTION OF SOIL AND SOIL GAS SAMPLES

INSERT 7. p. 45 following 2nd paragraph

In addition to the listed soil analyses, two soil analyses will be performed to evaluate benzene toluene, ethylbenzene, and xylene (BTEX) and total recoverable petroleum hydrocarbons (TRPH) and three soil gas analyses will be performed to evaluate BTEX and total volatile hydrocarbon (TVH).

SOIL

For each additional soil sample to be analyzed for BTEX and TRPH, one 2" diameter by 6" length thin walled, brass tube taken from a split spoon sampler, will be provided. These samples must be preserved by shipping at 4³C.

SOIL GAS

For each soil gas analyses, one SUMMA\ canister will be provided. This is not to be chilled or preserved for shipping.

INSERT 8. p. 48, Section 5.7.1, 1st paragraph, last sentence Figure 2-9 should read 5-2.

INSERT 9. p. 48, Section 5.7.1 following 1st paragraph.

HELIUM INJECTION

The key to successful helium diffusion testing is to provide a uniform injection concentration of helium. This requires regular checks on helium injection concentrations at the well head and may require adjustment of the two-stage regulator controlling helium and air injection to the monitoring point. A helium mixing device provided by ES-Denver will be used to inject a constant helium concentration into multiple wells.

INSERT 10. p. 53, Section 5.7.2, replaces 2nd paragraph.

Battelle and AFCEE have determined that helium loss cannot be quantitatively related to oxygen diffusion. Helium will be used as a conservative tracer to detect serious leakage or short-circuiting in each monitoring point used for respiration testing. If a monitoring point loses over 75% of its initial helium concentration in the first 1000 minutes of respiration testing, that monitoring point will be considered unacceptable for respiration testing.

INSERT 11. p. 29 Replace Figure 4-1 with the following figure.

INSERT 6. p. 44 Replace title of Section 5.5

5.5 COLLECTION OF SOIL AND SOIL GAS SAMPLES

INSERT 7. p. 45 following 2nd paragraph

In addition to the listed soil analyses, two soil analyses will be performed to evaluate benzene toluene, ethylbenzene, and xylene (BTEX) and total recoverable petroleum hydrocarbons (TRPH) and three soil gas analyses will be performed to evaluate BTEX and total volatile hydrocarbon (TVH).

SOIL

For each additional soil sample to be analyzed for BTEX and TRPH, one 2" diameter by 6" length thin walled, brass tube taken from a split spoon sampler, will be provided. These samples must be preserved by shipping at 4°C.

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For each soil gas analyses, one SUMMA® canister will be provided. This is not to be chilled or preserved for shipping.

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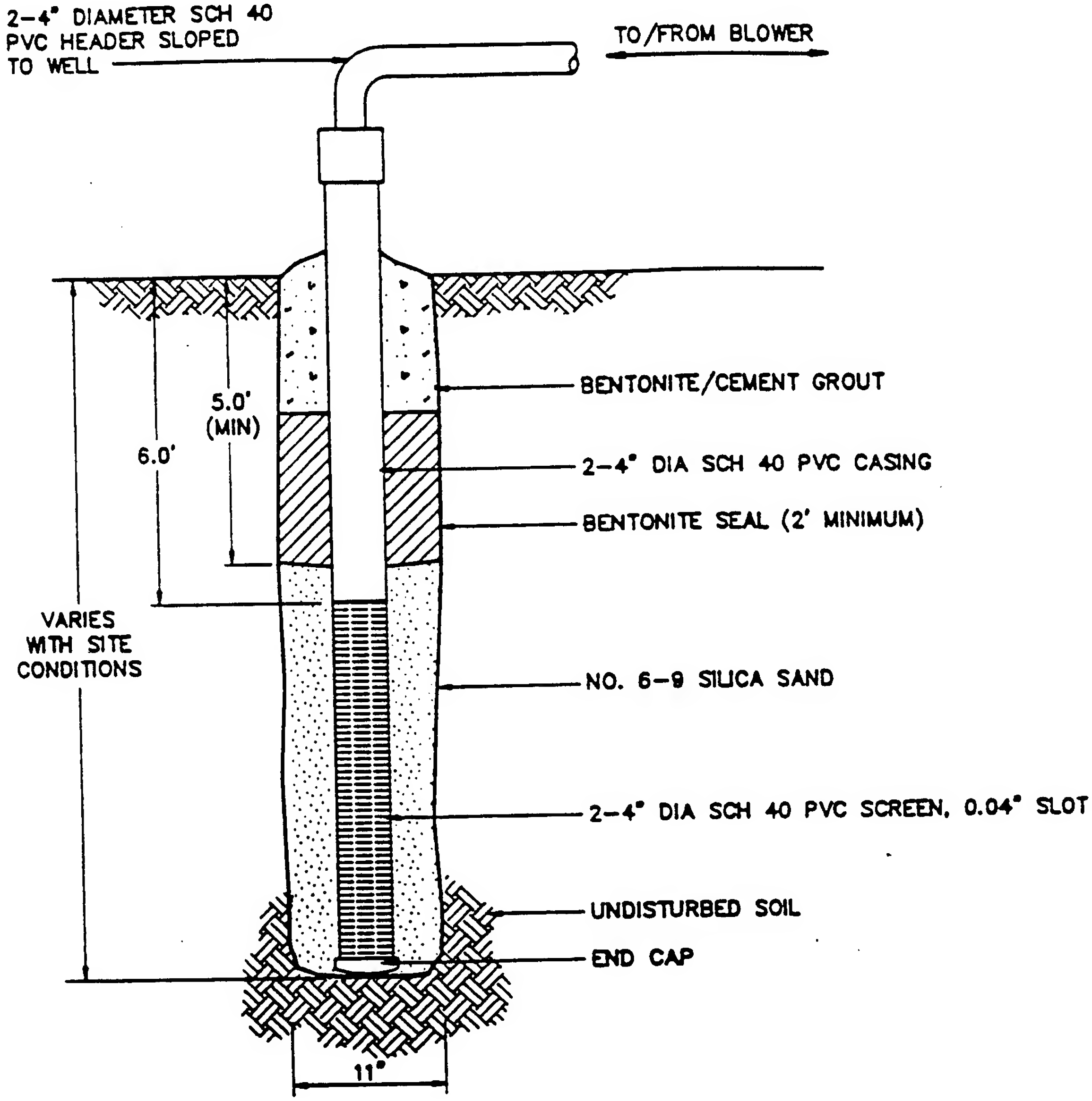
INSERT 11. p. 29 Replace Figure 4-1 with the following figure.



NOT TO SCALE

FIGURE D.5

TYPICAL
INJECTION/VACUUM VENTING
WELL CONSTRUCTION DETAIL

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN0199, 01/20/93 at 14:59

INSERT 12. p. 33 Replace Figure 4-2 with the following figure.

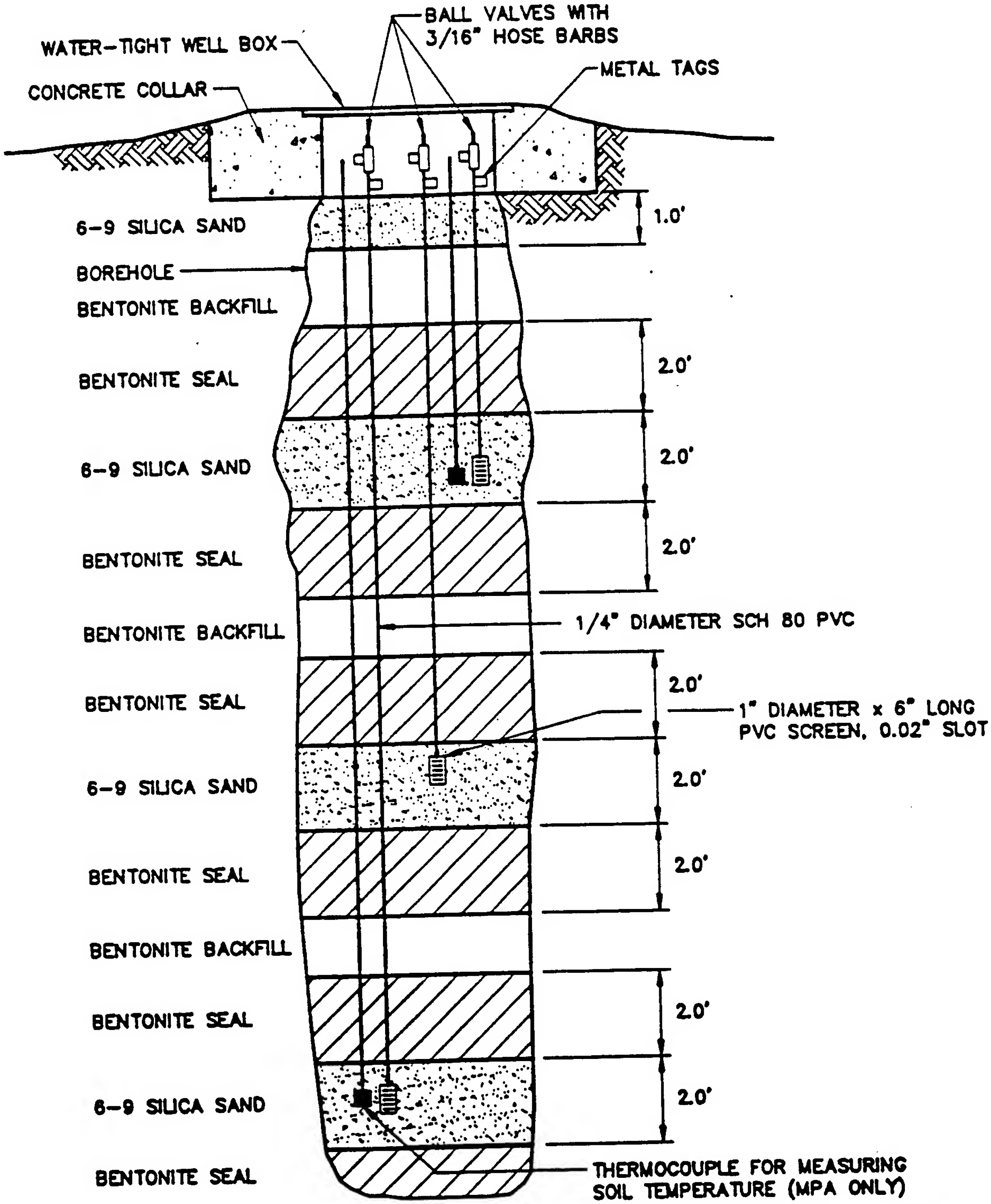


FIGURE D.6

TYPICAL MONITORING POINT CONSTRUCTION DETAIL

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN0164, 01/21/93 at 12:51

INSERT 13. p. 48 Insert the following figure.

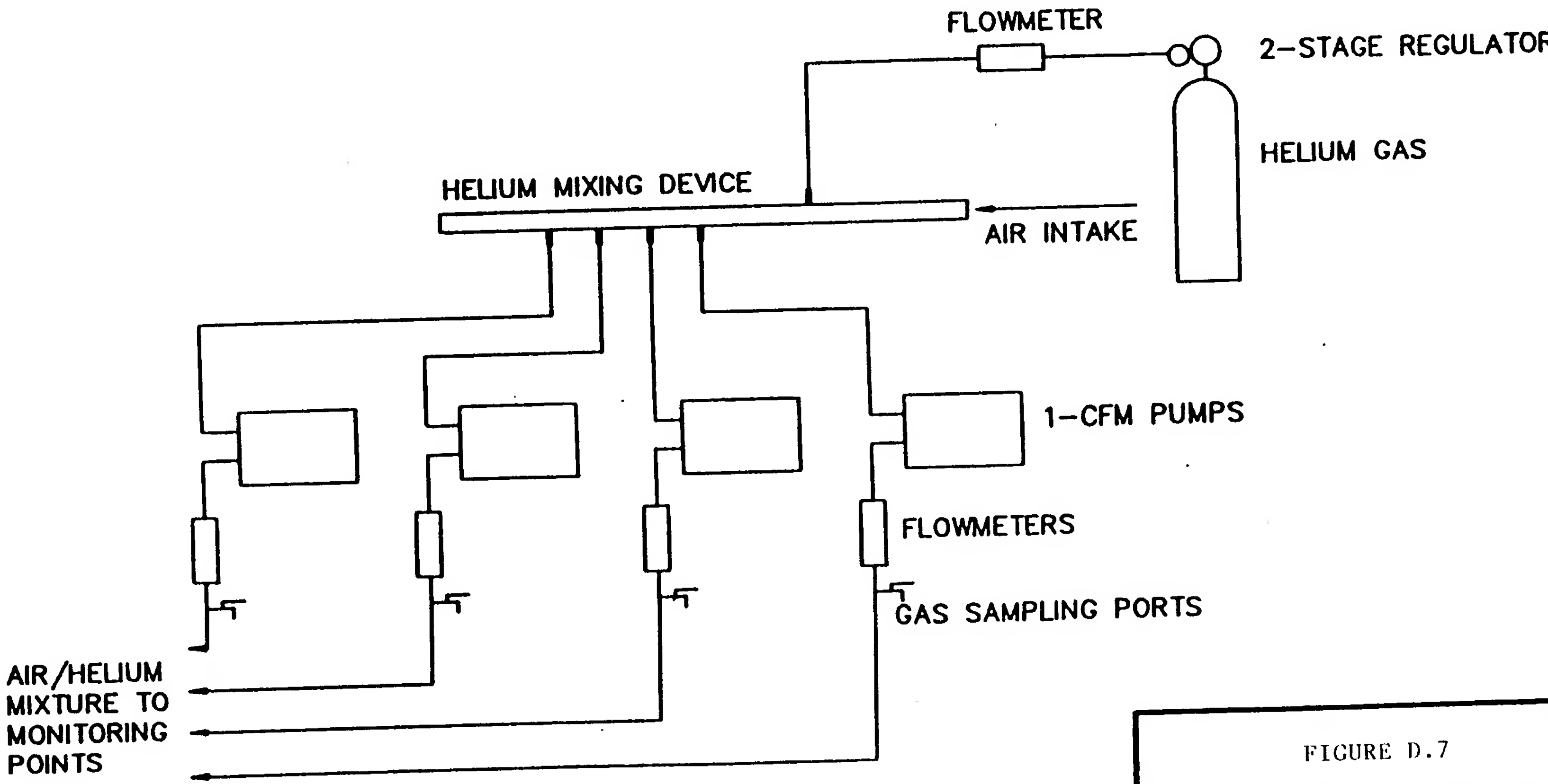


FIGURE D.7

TYPICAL AIR/HELIUM INJECTION APPARATUS FOR IN-SITU RESPIRATOR TESTS

ENGINEERING-SCIENCE, INC.
Denver, Colorado

03DN0209 01/25/03 at 14:23

PILOT TEST OUTLINE

AND

EQUIPMENT LIST

BIOVENTING PILOT TEST OUTLINE

1 PRE MOBILIZATION

- ELECTRICAL POWER READY?
- Air, drilling and other permits
- Work/Health and Safety Plans approved by base/regulators?
- Utilities cleared?
- Arrange to meet with electrician upon arriving on site
- Check supplies
- Hotel, airline, and vehicle rental reservations
- Security clearance information (ES and driller personnel)
- Potential background well information: existing groundwater monitoring well and/or location for new monitoring point outside contaminated area

2 DRILLING/SOIL SAMPLING

2.1 Pre-Drilling

- Meet with base contact
- Check utility clearance
- Soil gas survey: confirm low O_2 concentrations
- Locate water source
- Arrange for drum staging
- Establish decontamination area
- Drum labeling instructions/materials from base contact

2.2 Drilling

- Soil sampling: see Sampling Plan
- Collect one soil sample from VW, MPA, and MPB

2.3 MP Construction

- Install 2 thermocouples in MPA. Compare with mercury thermometer before installing

3 BASELINE MEASUREMENTS

- Purge MPs, VW; determine optimum purge times; check vacuum to determine if "egg" is needed for sampling
- Measure O_2, CO_2, and hydrocarbon concentrations
- Collect SUMMA air samples; MPA, MPC, VW
- Measure soil temperature

4. PERMEABILITY TEST

4.1 System Check

- Set-up, zero gages
- Measure initial pressures
- Check flow rate, injection pressure, pressure response at MPs
- Choose appropriate pressure gages

4.2 Permeability Test

- Run blower until steady state for pressure achieved and O_2 response measured at all/most MPs
- Measure post-test O_2, CO_2, and HC concentrations
- Measure soil temperature
- Begin respiration test for the VW

5. RESPIRATION TEST

- Continue measuring O_2, CO_2 and HC at VW
- Choose 3 or 4 MPs with low initial O_2 and high initial HC concentrations. Use MPs where soil samples collected.
- Inject helium/air mixture (2-5% Helium) using helium mixing manifold
- Inject air at background MP/well if initial O_2 concentration is less than 18 percent
- Inject air for 20 hours
- Measure flow rates and Helium concentrations during injection
- After injecting for 20 hours, begin measuring O_2, CO_2 HC, and helium concentrations
- Measure soil temperature

6. EXTENDED PILOT TEST BLOWER SYSTEM

- Set-up system
- Paint blower enclosure appropriate color to match nearby buildings; Check with base contact for proper color selection
- Measure O_2 concentrations at MPs
- Start blower and adjust air flow to VW. reduce air flow if short circuiting is occurring or strong fuel odor is noticed
- Check injection pressure, temperature, motor amps/voltage
- Set automatic pressure relief valve at or below maximum blower rating
- Set starter overload protection to 0.85 X amperage on motor nameplate (FLA) for single phase power
- If motor amperage too high, adjust manual bleed valve
- Run blower for approximately 24 hours and until O_2 change and pressure response is measured in all/most MPs
- Check injection pressure, temperature, relief valve setting (should not continuously release air), and motor amps. Make any necessary adjustments
- Train base personnel on system monitoring and maintenance
- Provide base with O&M manual (fill in the blanks !!), data sheets, and 2 spare filter elements (oil, grease, etc. for PD blowers)
- Leave key for blower enclosure with base contact

7. DEMOBILIZATION

- General site check
- Arrangement with base for disposal soil cuttings, decontamination water, etc.?
- Secure items in trailer; check trailer lights, brakes, tires, etc.

BIOVENTING PILOT TEST EQUIPMENT LIST

ITEM	NEEDED	NOT NEEDED	IN STOCK	ADD TO STOCK

SOIL GAS SURVEY

Jack				
Hammer				
Probe set				
Spare screens				
Tygon tubing, 1/8"				
Probe tips				
Probe tip screens				

DRILLING, SOIL SAMPLING, AND AIR SAMPLING

Alconox				
Baggies				
Boring logs				
Brass liners				
Brushes				
Caps, plastic				
Chain-of-Custody forms				
Decon buckets				
DI water				
Field books				
Garbage bags				
Haz Waste labels				
Keys				
Labels				
Locks				
Pin flags				
Sample jars				
Sampling Plan				
SUMMA canisters and adaptor				
Teflon squares				
Trowels				
Work plans & reports				

MONITORING POINT & VENT WELL CONSTRUCTION

Aluminum tags				
Hose barbs				
MP Flush-mount covers, 8"				
MP Screen assemblies				
MP Tops				
Hose barbs, 1/4" NPT x 3/16"				
1/4" ball valve				
Threaded adaptor				
Thermocouples				
VW Flush-mount covers, 12"				

METERS ETC.

Calibration gas				
O2/CO2 (5% CO2, 95% nitrogen)				
Helium				
Hexane (4400 ppm)				
Digital thermometer (for thermocouples)				
O2/CO2 meter				
Block-type flow meters				
0-3 SCFH (helium injection)				
0-100 SCFH (1 CFM sampling/injection pumps)				
0-40 CFM (measure bleed air)				
Helium detector				
TVH analyzer				
2-Stage regulator (for helium)				
1-stage regulator (for calibration gas)				

ITEM	NEEDED	NOT NEEDED	IN STOCK	ADD TO STOCK

HEALTH AND SAFETY

Calibration gas				
Draeger kit				
Explosimeter				
Eye wash				
First Aid Kit				
Gloves – inner				
Gloves – outer				
Gloves – leather				
Goggles/safety glasses				
Heath & safety plan				
Hard hats				
Hnu/TIP/TVHA				
Nuke boots				
Steel toe boots				
Rain gear				
Tyvek suits				

MISCELLANEOUS

Camera				
Extension cords				
Federal Express Forms				
Field Clipboard				
Film				
Flagging tape				
Generator				
Helium				
Light, clamp – on				
List of contacts				
Locks				
Paper towels				
Pens and Markers				
Pick axe				
Scissors				
Shovel				
SUMMA Canister adaptor				
Tape – Duct				
Tape – Clear				
Tool kit				

ITEM	NEEDED	NOT NEEDED	IN STOCK	ADD TO STOCK
AIR PERMEABILITY TEST				
Data sheets				
Magnehelic pressure gages				
0–1"				
0–5"				
0–10"				
0–20"				
0–50"				
0–100"				
0–150"				
Pilot test P.D. blower				
Air flow measurement				
Pitot tube				
Tubing				
0–0.25" gage				
0–0.50" gage				
2"–diameter x 5' long PVC				
4"–diameter x 8' long PVC				
Flexible connectors (Femco)				
1 1/2" x 2"				
1 1/2" x 4"				
2" x 2"				
2" x 4"				
4" Street ell				
2" Street ell				
RESPIRATION TEST				
Data sheets				
Helium mixing manifold				
Meters				
Portable pumps (1 CFM)				
Portable pump covers				
Tubing, 3/16"				
Tees				
Clamps				
VW top with 3/16" hose barb				
Regulator, helium				
EXTENDED TEST BLOWER SYSTEM				
Air filters				
Air filter elements (spare)				
Blower (and alternate ?)				
Blower enclosure				
Bleed valve (gate valve)				
Misc. pipe fittings				
1 1/2" for regenerative blower				
3/4" for rotary vane blower				
Pressure gage (dial)				
Pressure relief valve (automatic)				
PVC and/or iron pipe fittings				
VW top				
Blower to VW				
Gages, dial type (vacuum & pressure)				
Starter (and alternate ?)				
Thermometer (dial)				